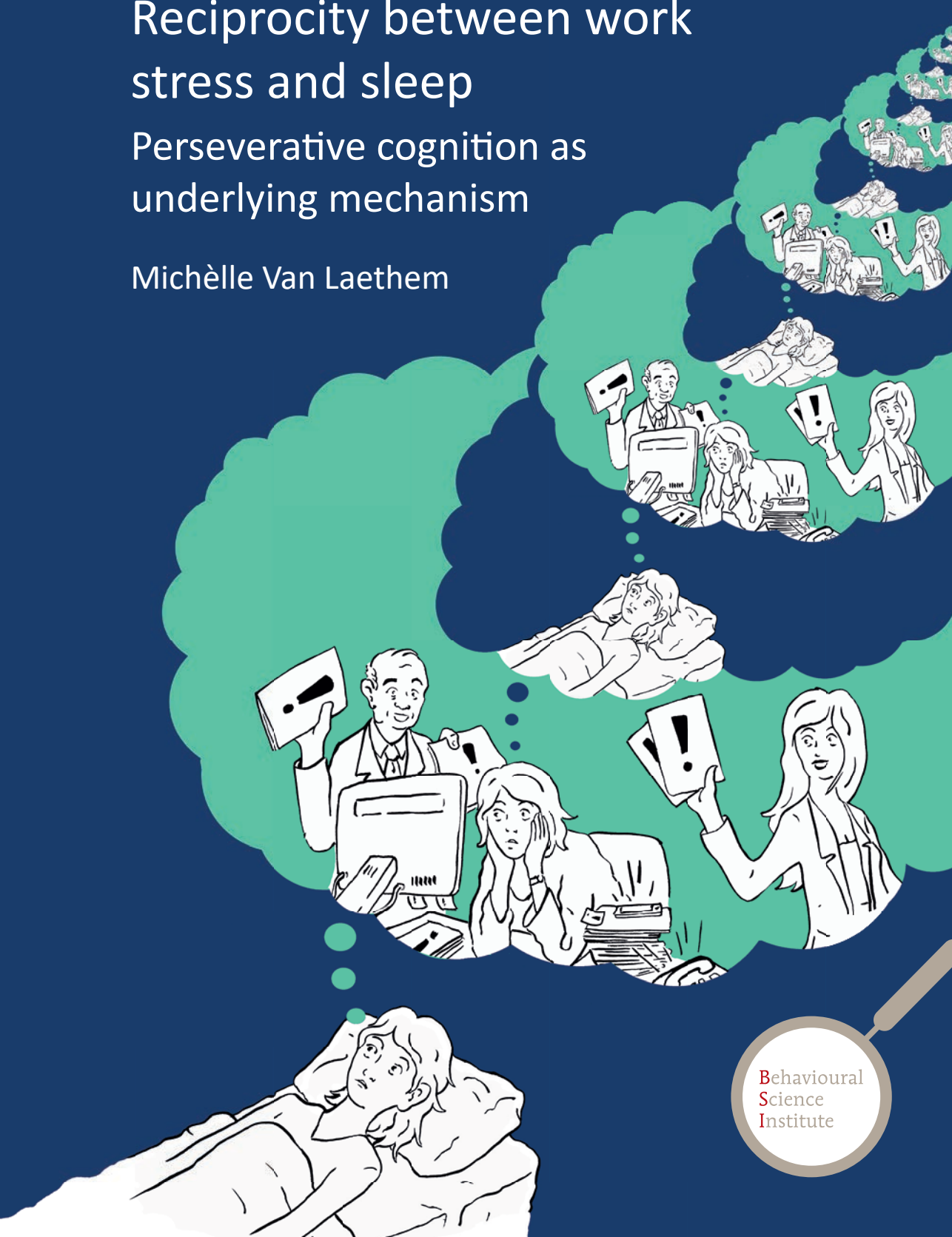
Reciprocity between work stress and sleep

Perseverative cognition as underlying mechanism

Michèlle Van Laethem



Behavioural Science Institute

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Für Mama

Ohne dich wäre ich nicht da, wo ich heute bin.

CONTENTS

Chapter 1

General introduction

Tomorrow, a stressful event is awaiting you. You have an exam, a job interview, or an important business meeting. You are lying in bed, tossing and turning, and you just cannot fall asleep because you are continuously thinking about the impending significant event. Ironically, the fact that you are not getting a good night's sleep is making you yet more worried. Your stress levels become even higher, and may deteriorate your performance during the exam, the interview, or the meeting.

Most of us can relate to this scenario. Stress, especially stress related to work, and associated sleep problems are common nowadays. A survey by Eurofound (2015) established that about one third of European employees experience high work stress. Additionally, many employees worry about their work in their free time, and 14% does so on a regular basis (Eurofound, 2015).

Occupational health research has consistently shown that a highly demanding work situation can be a source of work stress (Crawford, LePine, & Rich, 2010; Häusser, Mojzisch, Niesel, & Schulz-Hardt, 2010; Kamarck et al., 2002). Exposure to demanding work is very prevalent: 60% of European employees work regularly at very high speed and to tight deadlines (Eurofound, 2015). Work, particularly under stressful conditions, requires cognitive, emotional, and/or physical effort that is associated with psycho-physiological load effects. According to Effort-Recovery theory (Meijman & Mulder, 1998), recovery during or after work is crucial to reduce these load effects and to let stress-related psycho-physiological systems return to baseline (pre-demand) levels (Geurts & Sonnentag, 2006). Sufficient recovery thus allows for a refreshed start.

When recovery is incomplete while facing new cognitive, emotional, and/or physical challenges, compensatory effort is needed to adequately meet these challenges, thereby further increasing the demands on the recovery process. As a result, psycho-physiological load effects are likely to accumulate. Following McEwen's (1998) Allostatic Load theory, this imbalance between effort and recovery will result in an adverse bodily state called 'allostatic load' which has negative consequences for health in the long run (Hammen, 2005; Kivimäki & Kawachi, 2015; Maslach, 1993; McEwen, 2008). Although the relations between demanding work, stress, and adverse health have been studied, little is known about the actual day-to-day and week-to-week time course of stress and recovery in the face of a stressful event. Similarly, not much is known about the quantity or quality of recovery needed to prevent accumulation of load effects. Understanding this time course may contribute to our understanding of the interplay between stress exposure, recovery opportunities, and health.

In light of the prominent role of sufficient recovery in upholding health, it is important to focus on sleep as 'the recovery opportunity par excellence' (Åker-

stedt, Nilsson, & Kecklund, 2009; Rook & Zijlstra, 2006). Whereas sleep promotes psychophysiological recovery from stress and is vital in averting ill-health, stress may impede good sleep due to physiological and cognitive arousal (Åkerstedt et al., 2009). Indeed, research has shown that sleep complaints are present in about one-third of the Western population (LeBlanc et al., 2009; Ohayon & Reynolds, 2009). There are indications that stress-related cognitive processes, like worrying and rumination, are key factors in stress-related sleeping difficulties (Åkerstedt et al., 2009). In the scientific literature, such a negative thought process is often coined 'perseverative cognition' (PC). More formally, PC is defined as "repeated or chronic activation of the cognitive representation of one or more psychological stressors" (Brosschot, Gerin, & Thayer, 2006, p. 114).

To date, only few researchers have examined the relations between stress, PC, and sleep. As far as scientific research is concerned, its nature was mainly cross-sectional, pointing at a strong negative relation between (work) stress and sleep (Åkerstedt et al., 2009). Not many studies used longitudinal designs with a focus on the temporal characteristics of the work stress–sleep relationship (Geurts & Sonnentag, 2006; Van Laethem, Beckers, Kompier, Dijksterhuis, & Geurts, 2013), and hence, the more minute temporal aspects of the relation between stress and sleep are not well understood. Furthermore, since research studying PC as an underlying mechanism in the work stress-sleep relationship is scarce, the exact role of PC in this relationship is still unclear (Van Laethem et al., 2013; Verkuil, Brosschot, Gebhardt, & Thayer, 2010). Attempting to fill these gaps in knowledge, the main objectives of this dissertation were to examine:

(i) the temporal relations between work-related stress(ors), PC, and sleep,
(ii) the role of PC as a potential underlying mechanism in the stress-sleep relationship,
(iii) the development of stress and sleep over time.

Related to these key-objectives, in the remainder of this chapter, I will outline the theoretical framework of this dissertation. First, the concept of work stress will be further introduced, and the distinction between work stressors and stress responses will be clarified, while providing a more in-depth discussion on the relevance of recovery. Related to recovery, in this first part, sleep quality will be discussed in more detail, and different methods of measuring sleep will be explained. Additionally, the relationship between stress and sleep will be reviewed. Second, PC will be introduced as a credible and potentially crucial explanatory mechanism in the stress-sleep relationship. Third, gaps in previous research will be discussed as well as attempts of the research presented in this dissertation

to bridge these gaps. Moreover, an overview will be given of the main research questions guiding this dissertation. Finally, I will provide an outline of the chapters in this dissertation.

1.1 STRESS AND SLEEP

1.1.1 Stress

According to Kristensen and colleagues (1998), stress is both a subjective and physiological state accompanied by displeasure and high arousal. More specifically, work-related stress can be defined as emotional, cognitive, behavioural, and physiological reactions to negative aspects of work (Levi & Levi, 2000). In occupational health research, these negative aspects of work are coined work stressors, i.e. demanding work characteristics that evoke a psycho-physiological stress response (i.e., stress). The psychosocial work environment provides many potential stressors that relate to job content, including both functional and social elements, such as high job demands, low job control, or adverse social interactions (Karasek, 1979; Kompier, 2003). Ample research has shown that psychosocial work stressors are risk factors for stress and can have harmful effects on an individual's mental and physical health (Hammen, 2005; Maslach, 1993; McEwen, 2008; Steptoe & Kivimäki, 2012).

Research has demonstrated that the body triggers activation of physiological (stress) systems in response to encountered stressors (i.e., fight or flight response). Two main physiological systems that react to these stressors are the Sympathetic–Adrenal–Medullary (SAM) system and the Hypothalamic–Pituitary–Adrenal (HPA) system (Clow, 2001). The SAM system regulates cardiovascular activity (increased heart rate and blood pressure), whereas the HPA system mobilizes extra energy through the production of cortisol, the so-called 'stress hormone'. The HPA system is strongly linked to stress responses, whereas the SAM system has a more general and acute purpose in releasing (nor)adrenaline into the bloodstream to mobilize effort for dealing with a stressor or any other demand.

The 'reactivity hypothesis' states that negative effects of stress on health are caused by intense physiological reactions that arise during exposure to stressful situations (Verkuil et al., 2010). However, recent research suggests a more complex picture. Physiological activity occurring in anticipation of, or continuing after a stressful situation is more predictive of ill health (Brosschot et al., 2006; Geurts, Beckers, & Tucker, 2014; Pieper & Brosschot, 2005) than stress reactivity during a stressful event. That is, physiological activity in anticipation of or in response to a stressor will impair health, especially so when it occurs long before or persists long

after the stressful situation. These recent insights shift the emphasis of research from the stress response itself to psycho-physiological arousal in anticipation of a stressor and (insufficient) psycho-physiological recovery after stress exposure. As such, it is important to focus on recovery from stress to arrive at a better understanding of the long term effects of stress on health.

1.1.2 Recovery

Insufficient recovery seems to be an important explanatory mechanism in understanding the adverse impact of stress on health (Geurts & Sonnentag, 2006). After a stressful working day, such as when one is exposed to very high work demands or interpersonal conflicts, individuals require a period of recuperation to restore energy and let the stress response wear off (Meijman & Mulder, 1998). According to Effort-Recovery theory (Meijman & Mulder, 1998), load reactions (e.g., fatigue, elevated heart rate) are caused by expending effort and coping with stressors. As soon as stressors disappear, for instance during free evenings and weekends, those acute load reactions should return to baseline levels. This process is termed recovery. To fully recover from work effort, the interval between work periods should be long enough for load effects to disappear. If psycho-physiological systems have not returned to baseline levels when facing a new demand (e.g., a subsequent working period), recovery is incomplete. Compensatory effort is needed to deal with this new demand, which adds to the burden on the recovery process and may ultimately result in accumulation of psycho-physiological load effects. In case of long term exposure to an imbalance between effort and recovery, chronic load reactions will develop (Geurts & Sonnentag, 2006).

At this point, McEwen's (1998) Allostatic Load theory complements the Effort-Recovery theory. McEwen describes allostatic systems (e.g., SAM system, HPA system, and immune system) as initially adaptive: they protect the individual in such a way that he/she can deal adequately with potential stressors. The core assumption of this theory is that chronic activation of these allostatic systems (implying insufficient recovery) will result in a physiological adverse state named 'allostatic load'. Allostatic load refers to either overactivity (hyperactivity) or inactivity (hypoactivity) of the crucial psycho-physiological systems, in turn resulting in chronic sleep problems, burnout, and/or cardiovascular disease (Kristensen et al., 1998; Maslach, 1993; Sluiter, Frings-Dresen, Van der Beek, & Meijman, 2001). Together, Effort-Recovery theory (Meijman & Mulder, 1998) and Allostatic Load theory (McEwen, 1998) emphasize the relevance of recovery from (work) stress in upholding health.

1.1.3 Sleep

Sleep is one of the most powerful opportunities to recover from daily stress (Rook & Zijlstra, 2006). One of the benefits of sleep is the physiological restoration of bodily processes, which seem to counteract the impact of daily stress (Åkerstedt et al., 2009). Both sleep quality and sleep quantity are important for recovery. Sleep quantity represents the duration of sleep (Åkerstedt, Hume, Minors, & Waterhouse, 1994a; Åkerstedt et al., 2009). Poor sleep quality refers to sleep discontinuity and includes one or more of the following symptoms (Edinger et al., 2004): (i) difficulties initiating sleep, (ii) difficulties maintaining sleep, (iii) waking up too early, or (iv) non-restorative sleep. Both sleep quality and sleep quantity can be assessed subjectively and objectively (Landry, Best, & Liu-Ambrose, 2015). Subjective measures of sleep include self-reports and are easy to acquire, but the validity of subjective sleep assessments has been thoroughly debated. Objective measures include registration of sleep by means of technical devices and generally provide more valid assessments of aspects of sleep that are difficult for an individual to estimate (e.g., total sleep time, sleep onset latency, number of awakenings) (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Baker, Maloney, & Driver, 1999).

Subjective and objective sleep measures do not always correspond with each other (Landry et al., 2015; Unruh et al., 2008). A recent study (Westerlund, Lagerros, Kecklund, Axelsson, & Åkerstedt, 2016), for instance, compared objective sleep assessed with polysomnography to subjective sleep questionnaires and found that most subjective and objective sleep parameters (e.g., sleep duration, sleep onset latency), were not significantly correlated. It has been suggested that this difference results from the fact that both techniques assess different components of sleep. For example, subjective sleep quality may represent the more conscious aspects of sleep, such as the extent to which one feels refreshed in the morning or (the length of) wakeful episodes at night. Conversely, objective sleep quality may measure sleep on a micro or unconscious level, for example, it assesses the number of (micro)awakenings during the night. Despite, or perhaps because of, their differences, both methods offer important insights into sleep and have complementary value (Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008; Landry et al., 2015; Tworoger, Davis, Vitiello, Lentz, & McTiernan, 2005). Hence, including both objective and subjective measures of sleep benefits the validity of results (Van Laethem et al., 2015).

1.1.4 Relation between stress and sleep

Stress typically generates high physiological activation, which impedes sleep (Åkerstedt et al., 2009). Higher stress appears to be correlated with decreased

sleep efficiency, i.e. longer time to fall asleep (sleep onset latency), and more awakenings during the night. Especially demanding or adverse psychosocial work characteristics, in particular long working hours, high workload, and work-family conflict, appear to be strongly associated with disturbed sleep (Dahlgren, Kecklund, & Åkerstedt, 2005). Previous research on the stress(or)-sleep relationship is mainly cross-sectional in nature, but more recently, some longitudinal studies have been conducted. The majority of these studies showed a negative, temporal relationship between stress(ors) and both sleep quantity and quality (Åkerstedt, 2006).

Experiencing sleeping difficulties appears to be related to serious health problems in the long run, such as depression and cardiovascular disease (Maglione et al., 2014; Vgontzas, Liao, Bixler, Chrousos, & Vela-Bueno, 2009; Wolk, Gami, Garcia-Touchard, & Somers, 2005). Moreover, sleeping periods shorter than 7 hours and longer than 8 or 9 hours are associated with higher mortality risks (Cappuccio, D'Elia, Strazzullo, & Miller, 2010). Additionally, sleep complaints have been shown to have negative effects on work performance; they are related to difficulties with concentration, lower work efficiency, higher absenteeism, and increased frequency of work-related accidents (Åkerstedt, Kecklund, Alfredsson, & Selen, 2007; Léger, Guilleminault, Bader, Lévy, & Paillard, 2002; Rosekind et al., 2010; Swanson et al., 2011). These findings emphasize that sleep is a key opportunity to recover from stress and to avoid health problems, but ironically, increased stress is likely to jeopardize recovery and sleep.

1.2 THE ROLE OF PERSEVERATIVE COGNITION

Geurts (2011, 2014) suggests that three types of factors can impact recovery after stress exposure and may ultimately influence sleep: cognitive processes, affective processes, and behaviour. In this dissertation, I am particularly interested in the cognitive process of perseverative cognition (PC). Brosschot and colleagues (2006) use the term 'perseverative cognition' as an overarching term including rumination and worry about past or future stressors. The authors presented the 'perseverative cognition hypothesis' and argue that cognitive representations of stressors generate physiological responses that are similar to physiological responses present during actual exposure to stressors or stressful events. Such prolonged mental representations of a stressful event (that is, the PC's) are thus expected to extend to psycho-physiological (e.g. cardiovascular) activation, which then hampers the recovery process (e.g., sleep), ultimately undermining health (cf.

Ottaviani et al., 2016). As such a mediating role for PC in the stress-sleep (recovery) relationship is suggested.

Field research has shown that particularly *work*-related PC is accountable for prolonged physiological activation and recent research provided evidence for a relation between work stress(ors) and PC (Brosschot, 2010; Pieper, Brosschot, Van der Leeden, & Thayer, 2007; Verkuil, Brosschot, Gebhardt, & Korrelboom, 2015). Moreover, research has demonstrated that work-related PC is related to sleep problems (Åkerstedt, Nordin, Alfredsson, Westerholm, & Kecklund, 2012; Cropley, Dijk, & Stanley, 2006; Kompier, Taris, & Van Veldhoven, 2012; Weise, Ong, Tesler, Kim, & Roth, 2013). In line with these findings, we assume PC to mediate the stress(or)-sleep relationship. However, the precise role of PC in the stress(or)-sleep relationship remains unclear.

1.3 LIMITATIONS OF EXISTING RESEARCH

1.3.1 Design and measures

The role of PC as an underlying mechanism of the stress-sleep relationship has not been examined in detail. Many researchers suggest that PC may play an important role, but not many have examined PC as a mediator in the stress-sleep relationship (Åkerstedt et al., 2009). One cross-sectional study has investigated the mediating role of PC in the relationship between stressors and sleep and found first indications that PC indeed mediates this relationship (Berset, Elfering, Lüthy, Lüthi, & Semmer, 2011). However, few researchers simultaneously included stress, PC, and sleep in their research. Most studies on this topic have focused either on the relation between stress and sleep or between stress and PC.

Moreover, research is often cross-sectional and in most research only subjective measures of sleep have been used (Åkerstedt, Knutsson, et al., 2002; Berset et al., 2011; Cropley et al., 2006; Kompier et al., 2012). Few studies have used objective measures or high-quality designs (Pereira, Meier, & Elfering, 2012; Weise et al., 2013) and many of the research designs used by previous research were not suited to provide insight into temporal relationships or mediation (Åkerstedt et al., 2009; Van Laethem et al., 2013). Some well-designed experimental studies do exist (Key, Campbell, Bacon, & Gerin, 2008; Verkuil et al., 2015). Most of this experimental research, however, only focuses on the association between stress and PC and typically stress is manipulated in a laboratory setting (Gerin, Davidson, Christenfeld, Goyal, & Schwartz, 2006; Glynn, Christenfeld, & Gerin, 2002; Radstaak, Geurts, Brosschot, Cillessen, & Kompier, 2011).

Longitudinal field studies are necessary to confirm results that were found in a laboratory setting and should improve generalization of conclusions to the general population. Some longitudinal studies have been conducted (Van Laethem et al., 2013), but strong full-panel designs including over time measurements of stress(ors), PC, and sleep are rarely used. Full-panel longitudinal designs are warranted since these designs can shed light on potential reciprocal temporal relations, which are deemed plausible. In line with the 'stressor creation hypothesis' (Bowling & Jex, 2013; De Lange, Taris, Kompier, Houtman, & Bongers, 2005; Spector, Chen, & O' Connell, 2000), it is legitimate to not only expect that exposure to stress(ors) results in more PC and deterioration of sleep, but to also expect that poor sleep, in turn, has a negative impact on PC and (the appraisal of) stressors. Poor sleep, for example, may increase *actual* stressors via decreased work performance and/or may alter how one *perceives* a work stressor (e.g., higher experienced job demands). Thus, high-quality longitudinal, full-panel designs are necessary to unravel the temporal relations between stress(ors), PC, and sleep and examine the role of PC as a possible mediator.

1.3.2 Development of stress and sleep over time

As described above, the Effort-Recovery theory (Meijman & Mulder, 1998) suggests that expending effort and being exposed to stressors may be harmful for health, but only in case of insufficient recovery over a prolonged period. If recovery is incomplete for an extended time, normal signs of inadequate recovery, such as fatigue or elevated heart rate, may accumulate and become chronic, resulting in allostatic load (Geurts & Sonnentag, 2006; McEwen, 1998). The Effort-Recovery theory (Meijman & Mulder, 1998) and the Allostatic Load theory (McEwen, 1998) provide a theoretical understanding of the development of stress and sleep problems, but the actual time course of stress, recovery, and sleep is rarely investigated. Every employee experiences stress at some point in his or her working career, and often certain periods are characterized by high pressure and tight deadlines. It is relevant to examine whether exposure to stress during extended periods is harmful in the long run. Moreover, it is important to investigate whether sleep is affected by stressors or periods of high stress and, in addition, how long it takes to recover from the stress generated by these stressful periods. To arrive at a better understanding of the time course of stress and sleep in face of stressful working conditions or specific stressful events, it is important to examine the development and maintenance of stress. Hereby, examining the development of stress and sleep over time is not only essential in the long term (e.g., high pressure job over many years), but also in the shorter term (e.g., leading up to and following

a specific stressful event such as an exam or job interview mentioned at the start of this dissertation).

1.3.3 Contribution of this dissertation

Theoretically, this dissertation contributes by shedding light on (i) the temporal relations between work stress(ors), PC, and sleep, (ii) the role of PC in the stress-sleep relationship, and (iii) on the development of stress and sleep over time. Relations between stress, PC, and sleep have seldom been examined concurrently and the potential mediating role of PC has often been overlooked. Moreover, research has not thoroughly focused on the time course of stress and sleep.

The studies in this dissertation include a focus on reciprocity of all relationships. For example, we examine whether stress is related to subsequent sleep ('normal relation'), but also whether sleep is related to subsequent stress ('reversed relation'). 'Reciprocal' relations are present if normal and reversed relations occur at the same time. Additionally, we not only investigate person-level relations over a long period of time, but also investigate within-person, day-to-day or week-to-week variations. This is especially interesting because general levels of stress(ors) and sleep are known to be rather stable over a long period of time, while simultaneously varying on a daily basis (Mezick et al., 2009). Finally, we pay attention to the development of stress and sleep over time (long-term and short-term), as until now this was never properly investigated. The derived knowledge extends previous literature on the development of stress and sleep and gives a clearer image of the causality among the discussed constructs as well as a better idea of PC as potential underlying mechanism. See Figure 1.1 for an overview of the research model.

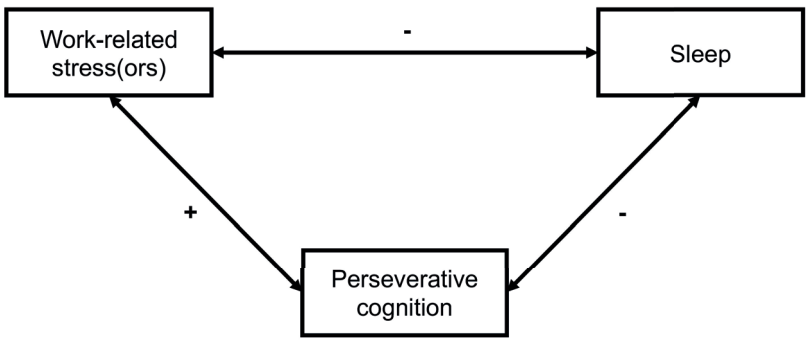

Figure 1.1 Research model investigated in this dissertation

Methodologically, this dissertation contributes by using strong study designs. In the studies presented in this dissertation, convincing research designs (i.e. full-panel longitudinal studies/long-term, longitudinal diary-based studies/short-term) were used to verify temporal relations between the three key concepts. Verification of temporal relations in the field of recovery from stress, especially for sleep as a recovery mechanism and PC as a mediator, is necessary since this research area has not been studied sufficiently yet. This dissertation attempts to clarify directionality of temporal relations of the discussed concepts by using high-quality research designs, which enable us to examine different types of temporal direction (i.e., normal, reversed, and reciprocal relations). This is important since we expect that, based on previous research (Åkerstedt et al., 2015; Åkerstedt et al., 2012; Cropley et al., 2006; Kompier et al., 2012), temporal relations between work stress(ors), work-related PC, and sleep exist and may be reciprocal.

In line with the above, this dissertation is guided by the following research questions:

1. Are work-related stress(ors), perseverative cognition, and sleep reciprocally related?
2a. Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *long* term?
2b. Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *short* term?
3a. How do work-related stress(ors) and sleep develop in the *long* term?
3b. How do work-related stress(ors) and sleep develop in the *short* term?

1.4 OUTLINE

This outline offers an overview of the specific research questions addressed in each chapter. A brief overview of the research questions and corresponding chapters are presented in Table 1.1.

In **chapter 2**, a systematic review on the longitudinal relation between work-related stressors and sleep quality is presented. In this review, all longitudinal and longitudinal intervention studies (published before 2012) were examined. Results were quantified with two methods: first, strength of evidence of all examined studies was assessed and subsequently, quality of the studies was evaluated based on predefined quality criteria. As such, we were able to examine a part of *research question 1* and provide an in-depth overview of previous literature.

Table 1.1 Overview of research questions and chapters

Research Question		Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
1	Are work-related stress(ors), perseverative cognition, and sleep reciprocally related?	X[a]	X	X		X[b]
2a	Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *long* term?		X	X		
2b	Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *short* term?					X[c]
3a	How do work-related stress(ors) and sleep develop in the *long* term?			X		
3b	How do work-related stress(ors) and sleep develop in the *short* term?				X	

Note: [a] = only work-related stressors and sleep quality; [b] = only normal causation relation; [c] = subjective and objective sleep

Research question 1 and *2a* were addressed in a full-panel longitudinal study, portrayed in **chapter 3**. In this longitudinal study with two waves and a time lag of one year, work-related stress, work-related PC, and sleep quality were measured on both time points. Structural equation modelling gave more insight into reciprocity of all concepts and provided first indications of the mediating role of PC in the stress-sleep relationship.

In **chapter 4**, another full-panel longitudinal study is presented to shed more light on *research question 1, 2a,* and *3a*. This longitudinal study consisted of three waves with two years in between measurements. Temporal, reciprocal relationships between job demands, work-related PC, and two dimensions of sleep quality (i.e., sleep disturbances and awakening problems) were modelled using structural equation modelling. Moreover, a mediation analysis gave more insight into PC as an underlying mechanism. Lastly, in this study, we took a closer look at individuals with continuous high job demands and how these 'chronic' job demands were related to sleep quality and work-related PC.

Research question 3b was tackled in a longitudinal diary-based study presented in **chapter 5**. In this study, the time course (development) of stress, fatigue, and sleep quality was examined within a group of PhD students awaiting and following a stressful life event (i.e., their dissertation defence). Moreover, it was also investigated whether anticipation leading up to the defence could predict stress, fatigue, and sleep quality on the day-level.

In **chapter 6**, the same group as in chapter 5 was studied, however, with the aim to answer a part of *research question 1* and *research question 2b*. In this longitudinal diary-based study, we set out to investigate the relations between stress, sleep, and PC on the day-level. Sleep was measured objectively and subjectively in this study and multilevel modelling as well as multilevel mediation shed more light on the relations between stress, PC, and sleep on the day-level.

In the final chapter of this dissertation (**chapter 7**), I will summarize and integrate the main findings of the separate studies, as well as all strengths, limitations, and practical implications.

Chapter 2

Psychosocial work characteristics and sleep quality: A systematic review of longitudinal and intervention research

Appeared as:

Van Laethem, M., Beckers, D. G. J., Kompier, M. A. J., Dijksterhuis, A., & Geurts, S. A. E. (2013). Psychosocial work characteristics and sleep quality: A systematic review of longitudinal and intervention research. *Scandinavian Journal of Work, Environment & Health, 39(6)*, 535-549.

ABSTRACT

The objective of this study was to review longitudinal and intervention studies examining the association between psychosocial work characteristics (e.g., job demands, job control, and social support) and sleep quality. Our main research aims were to examine whether (i) psychosocial work characteristics are a predictor of sleep quality, and (ii) sleep quality, in turn, is a predictor of psychosocial work characteristics. A systematic literature search resulted in 20 relevant papers, of which 16 were longitudinal studies and 3 were intervention studies (1 study was discussed in separate papers). To quantify results, we assessed the strength of evidence of all examined associations and subsequently evaluated the studies' research quality based on predefined quality criteria. One intervention and three longitudinal studies were categorized as being of high-quality. In longitudinal studies, we found consistent and strong evidence for a negative relation between job demands and sleep quality as well as evidence for a positive relation between job control and sleep quality. Other psychosocial work characteristics were examined in an insufficient number of (high-quality) studies. Moreover, both intervention studies as well as studies investigating reversed and reciprocal relations are rare, which further limits the possibility of drawing conclusions on causality. Based on the current literature, it can be concluded that high job demands and low job control are predictors of poor sleep quality. More high-quality research is needed to examine the possible causal relationship between these and other psychosocial work characteristics with sleep quality, in addition to research focusing on reversed and reciprocal relations.

2.1 INTRODUCTION

Sleep problems are highly prevalent in modern society. Approximately one third of people in Western countries experience sleep problems (e.g., short sleep duration, disturbed sleep continuity, overall dissatisfaction with sleep) multiple times a week and 7–9% can be diagnosed with insomnia according to DSM-IV criteria (LeBlanc et al., 2009; Ohayon & Reynolds, 2009; Stein, Belik, Jacobi, & Sareen, 2008). Self-reported insomnia symptoms, also referred to as poor sleep quality in the current study, includes ≥ 1 of the following complaints (Edinger et al., 2004): (i) difficulty initiating sleep, (ii) difficulty maintaining sleep (iii), waking up too early, or (iv) non-restorative sleep. Individuals must experience ≥ 1 symptoms for ≥ 3 nights per week to meet the criteria of poor sleep quality. To be diagnosed with clinical insomnia disorder, insomnia symptoms must be present longer than one month and individuals must experience daytime consequences in social, occupational or other areas of daily life (Ohayon & Reynolds, 2009).

Poor sleep quality has been linked to several health problems such as cardiovascular disease (Schwartz et al., 1999; Wolk et al., 2005), obesity (Patel & Hu, 2008), diabetes (Barone & Menna-Barreto, 2011), depression and anxiety (Lustberg & Reynolds, 2000; Roberts, Shema, Kaplan, & Strawbridge, 2000; Taylor, Lichstein, Durrence, Reidel, & Bush, 2005) , and is a risk factor for mortality (Cappuccio et al., 2010; Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Kripke, Langer, Elliott, Klauber, & Rex, 2011). Previous research has shown that (chronic) stress is an important antecedent of poor sleep quality and that work can be an important cause of stress (Åkerstedt, 2006). Many work-related stressors are psychosocial in nature (Karasek, 1979). Psychosocial work stressors refer to the job content including functional and social elements (e.g., excessive job demands, low job control, low social support at work) (Kompier, 2003). Considering the link between stress and sleep quality on the one hand, and work and stress on the other, one may hypothesize that unfavourable psychosocial work characteristics ('stressors') are related to reduced sleep quality.

Indeed, several studies have found a relation between work-related psychosocial stressors (i.e., high workload, job strain, cognitive and emotional job demands, job insecurity, bullying) and poor sleep quality (Dahlgren et al., 2005; Kompier et al., 2012; Lallukka, Rahkonen, Lahelma, & Arber, 2010; Niedhammer et al., 2009; Nomura, Nakao, Takeuchi, & Yano, 2009; Park, Nakata, Swanson, & Chun, 2012). Likewise, positive psychosocial work factors (i.e., social support, job control, organizational justice) have been linked to favourable sleep quality (Elovainio, Heponiemi, Sinervo, & Magnavita, 2010; Kompier et al., 2012; Nomura et al., 2009). However, most evidence is cross-sectional, preventing the possibility to draw

causal conclusions. This is a serious limitation that emphasizes the importance of longitudinal and intervention designs as such designs are needed to make stronger inferences about causality (Åkerstedt, 2006; De Lange, Taris, Kompier, Houtman, & Bongers, 2003; Kristensen, 2005; Taris & Kompier, 2003). Longitudinal and intervention designs also enable examining reversed relations: it seems plausible that if an individual develops poor sleep quality, this might alter the perception of the psychosocial work environment. De Lange et al. (2005) coined this within-person perceptual change the 'gloomy perception mechanism'. However, it is also likely that poor sleep quality influences the actual work situation. Poor sleep quality could lead to fatigue and also to poor work functioning and decreases in performance. Poor work performance, in turn, may also create work stressors, such as reduced support from colleagues or supervisors or insecurity (Kompier et al., 2012). This is what De Lange et al. (2005) define as the 'environmental change mechanism'.

We can conclude that it is important to empirically substantiate both normal and reversed relations between work characteristics and sleep quality, which requires at least longitudinal and intervention field study designs. The aim of this paper is to review the existing longitudinal and intervention studies on the assumed reciprocal relation between psychosocial work characteristics and sleep quality. The current systematic review aspires to answer two research questions: (i) do psychosocial work characteristics predict sleep quality (normal relation), and (ii) does sleep quality, in turn, predict psychosocial work characteristics (reversed relation)?

2.2 METHODS

2.2.1 Study selection

We performed an extensive literature search for longitudinal and intervention research on the association between psychosocial work characteristics and sleep quality (see Figure 2.1 for a complete overview of the search and selection procedure). This review focuses on the concept of sleep quality as defined in the introduction; even though sleep quantity is an important aspect of sleep as well (Ferrie, Kumari, Salo, Singh-Manoux, & Kivimäki, 2011; Ferrie et al., 2007), low sleep quantity alone does not suffice to characterize the experience of poor sleep. Therefore, studies only measuring sleep quantity were not included in this review.

A systematic search in three bibliographical databases was carried out [i.e., PsycINFO, PubMed (including Medline), Proquest Dissertations and Theses; final search date: 24 September 2012]. Search terms consisted of three groups

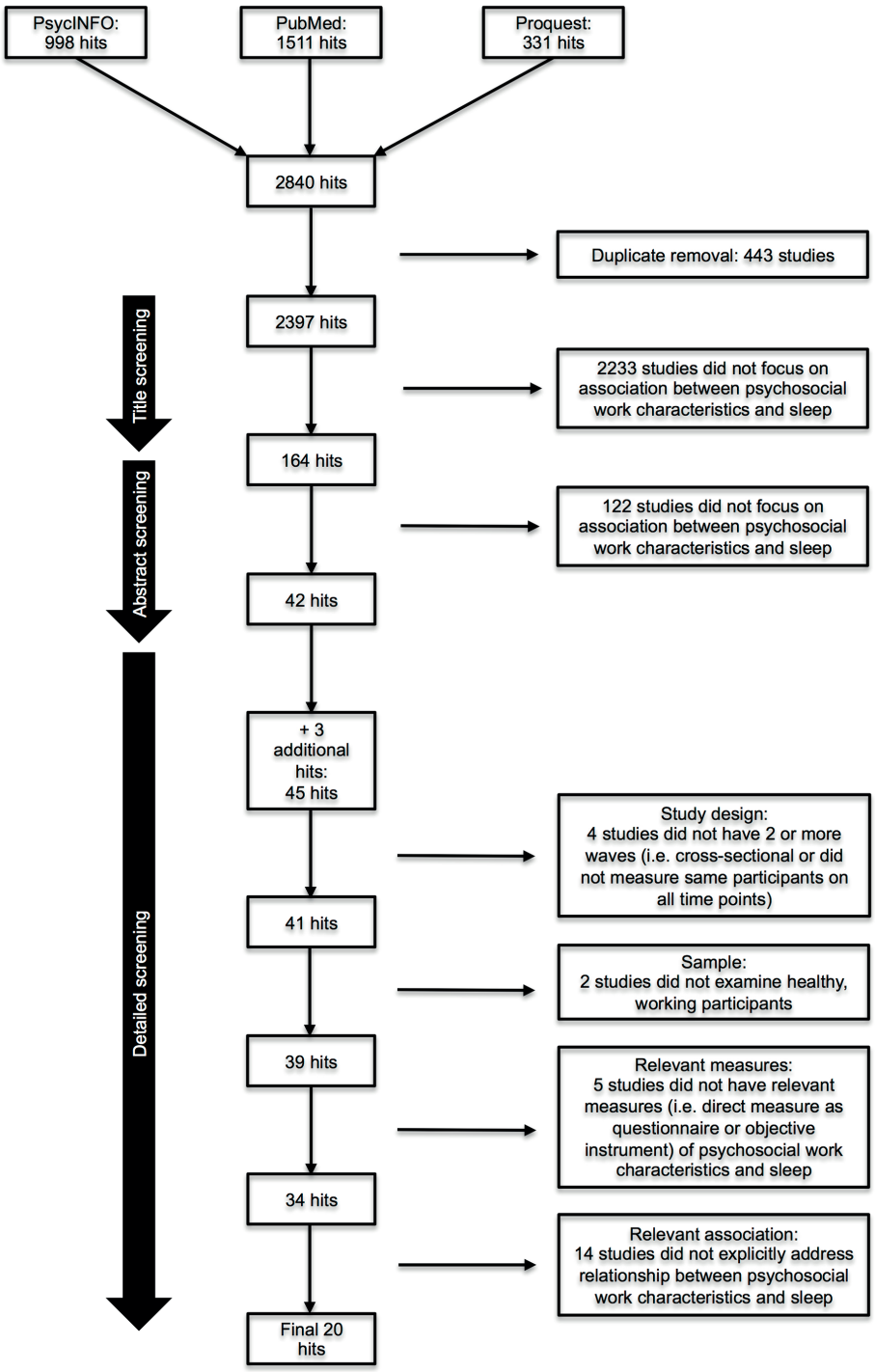

Figure 2.1 Systematic literature search and selection procedure

of keywords: "work characteristics" (e.g., job control), "sleep" (e.g., insomnia), and "longitudinal design" (e.g., prospective). The three categories were combined with the operator *AND*. Since our aim was to provide a broad overview of current longitudinal and intervention research, we included many search terms for both work characteristics and sleep quality to minimize the possibility of missing relevant studies. For a complete list of all search terms, see Table 1 in Appendix A. For the same reason, we did not restrict the search by publication year, language, publication type, or population. After removal of duplicates, the initial literature search resulted in 2397 hits.

The first author scanned all titles for relevance, which resulted in 164 remaining papers. Studies concerning work time or shift work were not included in this review, as work time per se is not considered a psychosocial work characteristic. Subsequently, all abstracts were retrieved and read by the first author. Studies were excluded if it was clear from the abstract that they did not examine psychosocial work characteristics in relation to sleep quality (e.g., studies focusing on infants). After screening all abstracts, 42 papers remained; 2 additional papers were added after consulting an expert in work–sleep research and 1 additional paper was retrieved after examining the reference lists of the 42 remaining papers. These 3 additional papers resulted in a total of 45 complete papers to be read.

While reading complete papers, studies were included based on the following criteria: (i) study design: ≥ 2 measuring points, (ii) sample: healthy, working individuals, (iii) relevant measures: direct measure of work characteristics and sleep quality by means of a questionnaire or objective instrument, and (iv) relevant association: relationship between psychosocial work characteristics and sleep quality explicitly addressed; some studies examined work characteristics and sleep quality (i.e., as covariates) but did not statistically test and report statistics on the direct relation between those variables. If a study did not comply with all criteria, it was excluded. After reading complete papers and applying inclusion criteria, 20 papers remained, of which two studies (Bourbonnais, Brisson, & Vezina, 2011; Bourbonnais et al., 2006) were taken together as one study, since the second paper was a follow-up measurement of the initial study. Moreover, two studies (Jansson & Linton, 2006; Jansson-Frojmark, Lundqvist, Lundqvist, & Linton, 2007) examined the same cohort, one of which concentrated on older workers. Both papers were included in this review and examined independently. Based on this selection procedure, 19 studies (i.e., 20 papers) were included in the present review.

2.2.2 Description and evaluation of results

Part I: Evaluation of all studies.

The results section of this review consists of two parts. The first part gives an overview of results of all included studies. Longitudinal studies examined a wide range of work characteristics of which some were only investigated by two or three studies. Additionally, studies used incomparable analytic approaches (i.e., logistic regression analysis and structural equation modelling). Therefore, it was not viable to perform a formal meta-analysis focusing on effect sizes of associations between each work characteristic and sleep quality [e.g., Hunter and Schmidt's method (Hunter & Schmidt, 2004)]. However, calculating a standardized index of convergence (SIC) is a feasible possibility to nevertheless quantify strength of the presented longitudinal evidence whilst avoiding mere 'vote-counting' (Nijp, Beckers, Geurts, Tucker, & Kompier, 2012; Wielenga-Meijer, Taris, Kompier, & Wigboldus, 2010). SIC can be defined as:

$$\frac{n[positive] - n[negative]}{n[total]}$$

In this formula, n[positive] corresponds to the number of studies reporting a significant positive association, n[negative] corresponds to the number of studies reporting a significant negative association, and n[total] corresponds to the total number of studies examining the association between a work characteristic and sleep quality (including studies that were not able to detect a significant relationship) (Wielenga-Meijer et al., 2010). The values of SIC can range between -1 (all studies reported a negative relationship) and +1 (all studies reported a positive relationship). If a SIC value is close to 0, evidence is either inconsistent or almost none of the studies were able to detect a significant association. SIC thus displays the degree of consistency of the evidence regarding a relation.

By combining the SIC score with the number of performed studies on a certain relationship (e.g., job demands and sleep quality), the strength of evidence for this relationship can be estimated. Table 2.1 shows possible outcomes for each studied relationship, depending on the SIC value and number of performed studies (Wielenga-Meijer et al., 2010).

Several studies reported multiple statistical tests. In this review, the most advanced analysis was used for SIC calculation (e.g., a model that adjusted for confounders was preferred over a model without confounder adjustment). Moreover, some studies reported multiple aspects of sleep quality (i.e., disturbed sleep and awakening problems, development and maintenance of poor sleep quality) or stratified sleep quality outcomes by gender (i.e., reported outcomes for men

Table 2.1 Strength of evidence for studies included in this review based on number of studies assessing each relationship and the corresponding SIC values

Number of studies	SIC				
	-1.00 to -.60	-.59 to -.30	-.29 to .29	.30 to .59	.60 to 1.00
1-2	#	#	#	#	#
3-5	- -	-	0	+	+ +
≥ 6	- - -	- -	0	+ +	+ + +

Note: 0 = inconsistent/no evidence for a positive/negative relationship, -/+ = limited evidence for a positive/negative relationship, - -/+ + = moderately strong evidence for a positive/negative relationship, - - -/+ + + = strong evidence for a positive/negative relationship, # = insufficient evidence for a positive/negative relationship

and women separately). These separate outcomes were taken together into one rating according to a decision tree (Figure 2.2), and this rating was subsequently included in our SIC calculation (Nijp et al., 2012).

Part II: High-quality studies.

To draw conclusions about the relations between work characteristics and sleep quality, one should rely more strongly on findings from high-quality studies. As such, apart from a complete overview of the results of all longitudinal and intervention studies (Results: Part I), we also performed a separate analysis of 'high-quality only' studies (Results: Part II). Therefore, all studies were rated in terms of quality criteria. Two sets of evaluation criteria were developed: one set to assess the quality of the longitudinal studies (see Table 2.2) and one set for the quality of intervention studies (see Table 2.3). The criteria were based on well-acknowledged insights from longitudinal and intervention research (De Lange et al., 2003; Kompier & Kristensen, 2000; Kristensen, 2005; Sax, Shannon, & Bryant, 2003; Taris & Kompier, 2003; Zapf, Dormann, & Frese, 1996). For each quality criterion, studies could be assigned zero, two, or three stars, corresponding to the quality ratings "insufficient", "sufficient", and "good".

2.2.3 Data extraction and quality assessment

The first author extracted data from all studies containing necessary information to assess a study's quality on each criterion. The second author verified all extractions, and discrepancies were discussed until consensus was reached. Next, the first and second author rated all studies independently and quality was determined according to the developed rating schemes (Tables 2.2 and 2.3). In case of disagreement on a quality assessment, this rating was resolved by consensus (initial convergence was on 96% of all ratings). To confirm whether our information

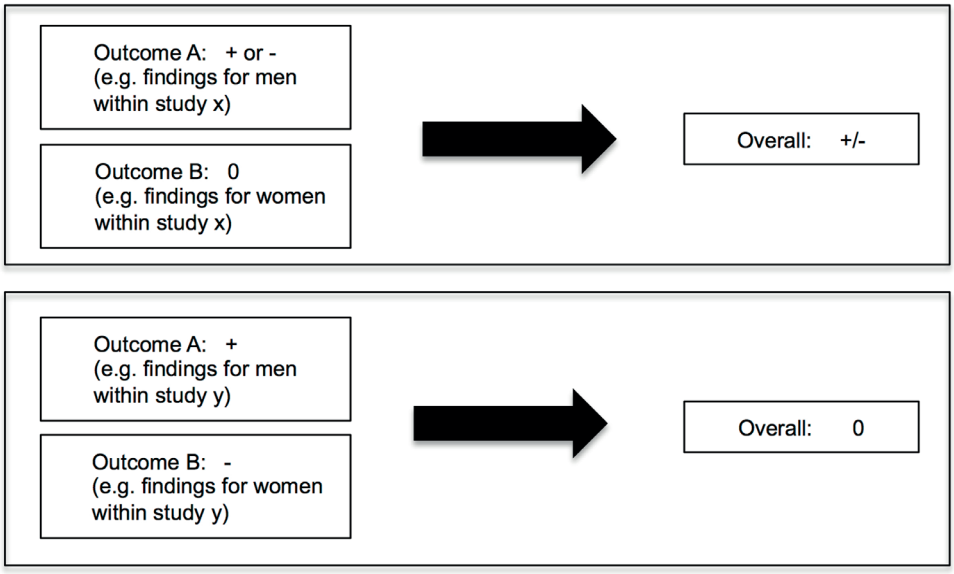

Figure 2.2 Decision rules to obtain a single rating based on multiple measures of the same outcome variable within one study
Note: + = significant positive relationship, - = significant negative relationship, 0 = non-significant relationship

about the studies was valid, all first authors of the 20 included papers (19 studies) were contacted by e-mail (longitudinal: 14 authors of 16 studies, intervention: 3 authors). Similar to De Lange et al. (2003), we explained the aim of our study and provided authors facts about their study that could be translated into quality ratings. After two months, 13 of the 17 authors had returned the factsheet (76% response rate).

Taken together, the authors responding to our e-mail checked 82 comments of which they felt that 7 were not entirely correct (91% agreement rate). We took this additional information into consideration and, in case of agreement, the quality ratings were adjusted accordingly. The comments resulted in six minor changes of our initial quality rating (Edme, Facq, Frimat, & Vezina, 2011; Lallukka, Rahkonen, & Lahelma, 2011; Virtanen, Janlert, & Hammarstrom, 2011; Wahlstedt & Edling, 1997).

A non-response analysis was performed to examine whether study quality differed between responding and non-responding authors. The mean quality scores (average number of achieved stars per study) of both groups were compared using an independent samples t-test, which was not significant [$t(17) = -1.59$, $p = 0.13$ (two-tailed): studies from non-responding authors [$M = 1.76$, $SD = 0.41$] did not significantly differ in quality assessment from studies of those who did respond ($M = 2.13$, $SD = 0.46$)].

Table 2.2 Evaluation criteria for longitudinal studies

Criteria	0 stars (insufficient)	** 2 stars (sufficient)	*** 3 stars (good)
1. Applied design	Incomplete panel design (2 TP, ≥ 1 central research variables measured only at 1 TP)	Incomplete panel design (> 2 TP, ≥ 1 central research variables measured more than once but not on all TP)	Complete panel design (All variables measured at each TP)
2. Measures: Sleep quality	- Unclearly formulated global one-item sleep quality measure, *or* - Clearly formulated global one-item sleep quality measure, but only 2 response categories, *or* - Facet sleep quality measure assessing only 1 out of 4 sleep quality aspects	- Clearly formulated global one-item sleep quality measure with clear response categories (> 2), *or* - Clearly formulated facet sleep quality measure assessing 2 out of 4 sleep quality aspects	Clearly formulated facet sleep quality measure assessing at least 3 out of 4 sleep quality aspects
3. Measures: Work characteristics	No work characteristics measured validly (i.e., no correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	Some, but not all, work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	All work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)
4. Non-response analysis	No check on selectivity of the sample	Check on selectivity of the sample either at baseline *or* follow-up	Check on selectivity of the sample at both baseline *and* follow-up
5. Statistical adjustment	**Either** no adjustment for: - Potential confounders, *and* - T1 dependent variables, *and* - Potential change of independent variables **OR** adjustment for potential confounders, but no adjustment for: - T1 dependent variables, *and* - Potential change of independent variables	Adjustment for potential confounders, **AND** adjustment for: - T1 dependent variables, *or* - Potential change of some independent variables	Adjustment for potential confounders, **AND** adjustment for: - T1 dependent variables, *and* - Potential change of independent variables

Note: TP = time point(s), JCQ = Job Content Questionnaire, ERI = Effort-Reward Imbalance Questionnaire, VBBA = Dutch Questionnaire on the Experience and Evaluation of Work, COPSOQ = Copenhagen Psychosocial Questionnaire

Table 2.3 Evaluation criteria for intervention studies

Criteria	0 stars (insufficient)	** 2 stars (sufficient)	*** 3 stars (good)
1. Control group and randomization	No control group or randomization	One control group, but no randomization	At least one control group and randomization
2. Measuring TPs: Sleep quality	Pre *or* post intervention only	Pre *and* post intervention	At least 1 pre *and* > 1 post intervention
3. Measuring TPs: Work characteristics	Pre *or* post intervention only	Pre *and* post intervention	At least 1 pre *and* > 1 post intervention
4. Intervention content	The initial problem (regarding psychosocial work characteristics and/or sleep quality) is not clear and/or intervention does not fit initial problem		The initial problem (regarding psychosocial work characteristics and/or sleep quality) is clear and intervention fits initial problem
5. Intervention process	No information about the implementation process is presented		Information about the implementation process is presented
6. Measures: Sleep quality	- Unclearly formulated global one-item sleep quality measure, *or* - Clearly formulated global one-item sleep quality measure, but only 2 response categories, *or* - Facet sleep quality measure assessing only 1 out of 4 sleep quality aspects	- Clearly formulated global one-item sleep quality measure with clear response categories (> 2), *or* - Clearly formulated facet sleep quality measure assessing 2 out of 4 sleep quality aspects	Clearly formulated facet sleep quality measure assessing at least 3 out of 4 sleep quality aspects
7. Measures: Work characteristics	No work characteristics measured validly (i.e., no correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	Some, but not all, work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	All work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)
8. Non-response analysis	No check on selectivity of the sample	Check on selectivity of the sample either at baseline *or* follow-up	Check on selectivity of the sample at both baseline *and* follow-up
9. Statistical adjustment	**Either** no adjustment for: - Potential confounders, *and* - T1 dependent variables **OR** adjustment for potential confounders, but no adjustment for T1 dependent variables		Adjustment for potential confounders, **AND** adjustment for T1 dependent variables

Note: TP = time point(s), JCQ = Job Content Questionnaire, ERI = Effort-Reward Imbalance Questionnaire, VBBA = Dutch Questionnaire on the Experience and Evaluation of Work, COPSOQ = Copenhagen Psychosocial Questionnaire

Since authors differ in terminology regarding sleep quality, we carefully checked whether each study examined sleep quality as defined in the introduction. Some authors distinguish between awakening problems and sleep disturbances (Magnusson Hanson et al., 2011), which are both aspects of sleep quality. To avoid confusion in the results section of this article, we employed the terminology used by the authors when reporting on these outcomes.

2.3.1 RESULTS (PART I: EVALUATION OF ALL STUDIES)

Longitudinal studies

Descriptive and background information.

Table 2 of Appendix A presents detailed information on the 16 longitudinal studies included in this review. In most studies, a heterogeneous group of employees was examined (N = 13, mixed occupations) (Åkerstedt et al., 2012; Burgard & Ailshire, 2009; De Lange et al., 2009; Edme et al., 2011; Elovainio, Kivimaki, Vahtera, Keltikangas-Jarvinen, & Virtanen, 2003; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Lallukka et al., 2011; Linton, 2004; Magnusson Hanson et al., 2011; Ribet & Derriennic, 1999; Rugulies, Norborg, Sorensen, Knudsen, & Burr, 2009; Virtanen et al., 2011), and groups of mixed gender were investigated in the majority of studies [N = 11; in two studies, groups with predominantly male participants were examined (Åkerstedt et al., 2012; Ota et al., 2009), and in three studies predominantly women (Elovainio et al., 2003; Eriksen, Bjorvatn, Bruusgaard, & Knardahl, 2008; Lallukka et al., 2011)]. All but one study were performed in Western countries (Åkerstedt et al., 2012; Burgard & Ailshire, 2009; De Lange et al., 2009; Edme et al., 2011; Elovainio et al., 2009; Elovainio et al., 2003; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Lallukka et al., 2011; Linton, 2004; Magnusson Hanson et al., 2011; Ribet & Derriennic, 1999; Rugulies et al., 2009; Virtanen et al., 2011) (N = 15, mostly European). The remaining study was conducted in Japan (Ota et al., 2009). Length of time lags (i.e., period between two measurement points) ranged from 3 months to 15 years and sample sizes ranged from 816–18695 participants.

Study design and quality assessment.

A full-panel design was used in four studies (Åkerstedt et al., 2012; Burgard & Ailshire, 2009; Magnusson Hanson et al., 2011; Virtanen et al., 2011). In most studies, however, an incomplete panel design was used with sleep quality measured at all time points and psychosocial work characteristics only at baseline (N = 11) (Edme et al., 2011; Elovainio et al., 2009; Elovainio et al., 2003; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Lallukka et al., 2011; Linton,

2004; Ota et al., 2009; Ribet & Derriennic, 1999; Rugulies et al., 2009). The remaining study also used an incomplete panel design, but had ≥ 2 time points (De Lange et al., 2009). All studies relied on self-report measures only; see Appendix A (Table 2). Seven studies (Åkerstedt et al., 2012; De Lange et al., 2009; Edme et al., 2011; Elovainio et al., 2003; Lallukka et al., 2011; Magnusson Hanson et al., 2011; Ota et al., 2009) used a clear measure of sleep quality, whereas four studies (Burgard & Ailshire, 2009; Elovainio et al., 2009; Linton, 2004; Virtanen et al., 2011) did not. Only ten studies (Åkerstedt et al., 2012; De Lange et al., 2009; Edme et al., 2011; Elovainio et al., 2003; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Lallukka et al., 2011; Magnusson Hanson et al., 2011; Ota et al., 2009) measured all 'their' work characteristics validly. Thirteen studies performed non-response analyses at baseline and/or follow-up (Åkerstedt et al., 2012; De Lange et al., 2009; Edme et al., 2011; Elovainio et al., 2009; Elovainio et al., 2003; Eriksen et al., 2008; Jansson & Linton, 2006; Lallukka et al., 2011; Linton, 2004; Magnusson Hanson et al., 2011; Ota et al., 2009; Ribet & Derriennic, 1999; Virtanen et al., 2011) (two studies: baseline and follow-up), and the remaining studies did not perform non-response analyses (Burgard & Ailshire, 2009; Jansson-Frojmark et al., 2007; Rugulies et al., 2009). In the majority of studies, logistic regression analyses (N = 12) were performed with sleep quality as outcome (Åkerstedt et al., 2012; Burgard & Ailshire, 2009; Edme et al., 2011; Elovainio et al., 2003; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Lallukka et al., 2011; Linton, 2004; Ota et al., 2009; Ribet & Derriennic, 1999; Virtanen et al., 2011). Two other studies explored the data with structural equation modelling (De Lange et al., 2009; Magnusson Hanson et al., 2011), and one used linear regression analysis (Elovainio et al., 2009). All studies investigated normal relations (work characteristics → sleep quality). Reversed relations (sleep quality → work characteristics) and/or reciprocal relations (work characteristics ↔ sleep quality) were examined in two studies (De Lange et al., 2009; Magnusson Hanson et al., 2011). Most studied work characteristics were job demands (N = 9), (dimensions of) job control (N = 10), and social support (N = 7). All other work characteristics were examined by ≤ 3 studies (i.e., effort–reward imbalance, organizational justice, influence over decisions, role conflict, and feedback).

The 16 longitudinal studies were rated according to our evaluation criteria (see Table 2.2). For each study, quality is depicted by a number of stars per criterion. Zero stars signify that a study is of insufficient quality on a particular criterion, two stars imply that a study scores sufficient on a criterion, and three stars (highest rating) mean that a study scores good on a specific criterion. Only when a study had at least two stars (sufficient quality) on each criterion, it was classified as an overall high-quality study. This procedure is based on the assumption that studies

scoring insufficiently on one or more quality criteria possibly suffer from certain biases, which make it impossible to draw definite conclusions on the effects and may reduce the validity of findings (De Lange et al., 2003). The resulting quality assessments are presented in Table 2.4. Of the 16 examined longitudinal studies three were of high quality (Åkerstedt et al., 2012; De Lange et al., 2009; Magnusson Hanson et al., 2011).

In the first part of the results section all studies are examined. We only discuss work characteristics measured in three or more studies. Outcomes of psychosocial work characteristics that were examined by less than three studies are nonetheless presented in Table 2.5 and Appendix A (Table 2). In the second part of the results section, we discuss the high-quality studies in more detail.

Table 2.4 Quality evaluation of longitudinal studies

Reference	1	2	3	4	5
Åkerstedt et al., 2012 [a]	•••	•••	•••	••	•••
Burgard & Ailshire, 2009	•••	0	0	0	•••
De Lange et al., 2009 [a]	••	•••	•••	••	•••
Edme et al., 2011	0	•••	•••	••	••
Elovainio et al., 2003	0	•••	•••	•••	0
Elovainio et al., 2009	0	0	0	••	••
Eriksen et al., 2008	0	••	•••	••	••
Jansson & Linton, 2006 [a]	0	••	•••	••	••
Jansson-Frojmark et al., 2007 [b]	0	••	•••	0	••
Lallukka et al., 2011	0	•••	•••	•••	••
Linton, 2004 [b]	0	0	0	••	••
Magnusson Hanson et al., 2011 [a]	•••	•••	•••	••	••
Ota et al., 2009 [b]	0	•••	•••	••	••
Ribet & Derriennic, 1999	0	••	0	••	0
Rugulies et al., 2009	0	••	0	0	••
Virtanen et al., 2011	•••	0	0	••	••

Note: 0 = insufficient, •• = sufficient, ••• = good, 1 = applied design, 2 = measures: sleep quality, 3 = measures: work characteristics, 4 = non-response analysis, 5 = statistical adjustment

[a] These studies were judged as at least "sufficient" on all five criteria and were thus considered high-quality studies

[b] These studies did not control for T1 dependent variables since they formed separate groups for good vs. poor sleep quality but statistical adjustment was nonetheless sufficient

Table 2.5 Number of studies and SIC values for all (normal relation) associations studied in three or more studies

Type of work characteristic	All longitudinal studies		High-quality longitudinal studies	
	SIC	*Strength of evidence*	*SIC*	*Strength of evidence*
Job demands	(0-7)/9 = -.78	- - -	(0-2)/3 = -.67	- -
Job control	(3-0)/10 = .30	+ +	(2-0)/3 = .67	+ +
Social support	(3-0)/7 = .43	+ +		
Effort-reward imbalance	(0-3)/3 = -1.00	- -		
Organizational justice	(2-0)/3 = .67	+ +		
Influence over decisions	(2-0)/3 = .67	+ +		
Role conflict	(0-1)/3 = -.33	-		
Feedback	(0-0)/3 = .00	0		

Note: 0 = inconsistent/no evidence for a positive/negative relationship, -/+ = limited evidence for a positive/negative relationship, - -/+ + = moderately strong evidence for a positive/negative relationship, - - -/+ + + = strong evidence for a positive/negative relationship, # = insufficient evidence for a positive/negative relationship

Longitudinal studies examining normal relations: job demands.

Nine studies examined job demands as a predictor of sleep quality. A negative relation between job demands and sleep quality was found in six of those studies (Åkerstedt et al., 2012; De Lange et al., 2009; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Ribet & Derriennic, 1999). Employees with higher job demands reported poorer sleep quality than employees with lower job demands. In one additional study, this relationship was found for men, but not women (Edme et al., 2011). A link between job demands and sleep quality could not be found in the remaining two studies (Linton, 2004; Magnusson Hanson et al., 2011), however, in one of those studies (Magnusson Hanson et al., 2011), the relation was marginally significant. Based on these nine studies the SIC value is: SIC(9) = -0.78, which indicates strong evidence for a negative relation between job demands and sleep quality.

Longitudinal studies examining normal relations: job control.

Job control was investigated in ten studies (Åkerstedt et al., 2012; Burgard & Ailshire, 2009; De Lange et al., 2009; Edme et al., 2011; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Linton, 2004; Magnusson Hanson et al., 2011; Ribet & Derriennic, 1999). Evidence for a significant positive relation between job control and sleep quality was presented in two of these (De Lange et al., 2009; Ribet & Derriennic, 1999). This means that employees who reported

more control over their job experienced better sleep quality. In another study, a significant positive effect was found for awakening problems but not for sleep disturbances (Magnusson Hanson et al., 2011). In the remaining seven studies, no significant effects were found. On basis of these ten studies the SIC value is: SIC(10) = 0.30, indicating moderately strong evidence for a positive relation between job control and sleep quality.

Longitudinal studies examining normal relations: social support.

The relationship between social support and sleep quality was examined in seven studies (Edme et al., 2011; Eriksen et al., 2008; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Linton, 2004; Magnusson Hanson et al., 2011; Ota et al., 2009). A positive relation was found in one of those studies, which indicates that employees reporting higher social support experienced better sleep quality (Eriksen et al., 2008). A positive effect of social support on sleep quality was revealed in a second study, but only for awakening problems and not for sleep disturbances (Magnusson Hanson et al., 2011). In another study, no link between social support and the development of poor sleep quality was found, but the authors could demonstrate an effect on maintenance of poor sleep quality (Ota et al., 2009). No significant relationship between social support and sleep quality was found in the remaining four studies (Edme et al., 2011; Jansson & Linton, 2006; Jansson-Frojmark et al., 2007; Linton, 2004). Based on these seven studies the SIC value is: SIC(7) = 0.43, indicating moderately strong evidence for a positive relation between social support and sleep quality.

Longitudinal studies examining normal relations: Other psychosocial work characteristics.

All remaining psychosocial work characteristics (i.e., effort–reward imbalance, organizational justice, influence over decisions, role conflict, feedback, bullying, or job insecurity) were examined in three or less studies. Table 2.5 depicts the number of studies and SIC values of the (normal relation) longitudinal relationships between psychosocial work characteristics and sleep quality of which a SIC score and strength of evidence could be determined. Outcomes of the remaining studies are presented in Table 2 of Appendix A. There is moderately strong evidence for a negative association between effort– reward imbalance and sleep quality [SIC(3) = -1.00], moderately strong positive evidence for organizational justice [SIC(3) = 0.67] and for influence over decisions [SIC(3) = 0.67], limited negative evidence for role conflict [SIC(3) = -0.33], and no evidence for a longitudinal relation between feedback and sleep quality [SIC(3) = 0.00].

Longitudinal studies examining reversed and/or reciprocal relation.

Of the 16 longitudinal studies, two also examined reversed and/or reciprocal relationships between psychosocial work characteristics and sleep quality (De Lange et al., 2009; Magnusson Hanson et al., 2011). These findings will be described in the same paragraph as the high-quality studies.

Intervention studies

Table 3 of Appendix A presents the main study characteristics of the intervention studies. Only three intervention studies could be identified, and each of them examined a homogeneous group of employees (Bourbonnais et al., 2011; Bourbonnais et al., 2006; Moen, Kelly, Tranby, & Huang, 2011; Wahlstedt & Edling, 1997). In two intervention studies, a mixed gender cohort was investigated, whereas in one study (two papers) participants were predominantly women (Bourbonnais et al., 2011; Bourbonnais et al., 2006). All studies were conducted in Western countries (Canada, US, and Sweden). Length of time lags ranged from six months to three years and sample size ranged from 100–334 participants.

Study design and quality assessment

In each intervention study, the authors attempted to change psychosocial work characteristics at the workplace (i.e., job demands, job control: skill discretion and decision authority, social support, effort–reward imbalance, and/or schedule control) with sleep quality as dependent variable. None of the intervention studies focused on modifying sleep habits. A control group was included in two of the three studies (Bourbonnais et al., 2011; Bourbonnais et al., 2006; Moen et al., 2011), but without randomization. In every study, at least one pre- and one post-intervention measurement was included for all variables. In all studies, the initial problem regarding psychosocial work characteristics was clear, the intervention fitted this problem, and information about the implementation process was presented. Studies used self-report measures only. Only one study (Wahlstedt & Edling, 1997) measured sleep quality with an unclearly formulated 1-item measure. Every study measured all work characteristics validly and performed non-response analyses at either baseline or follow-up. Analyses performed were ANOVA or ANCOVA (Bourbonnais et al., 2011; Bourbonnais et al., 2006), structural equation modelling (Moen et al., 2011), and oneway analysis of variance with multiple range tests using the least significant difference (LSD) procedure (Wahlstedt & Edling, 1997).

The three intervention studies were rated according to our evaluation criteria (see Table 2.3). If a study had at least two stars (sufficient quality) on each criterion it was classified as an overall high-quality study. The resulting quality assessments

are presented in Table 2.6. Of the three intervention studies examined, one was of high quality (Bourbonnais et al., 2011; Bourbonnais et al., 2006).

In this part of the results section, we consider all three intervention studies. In the second part of the results section, we examine the high-quality intervention study in more detail.

In two of the three intervention studies, most psychosocial work characteristics had improved, however, no significant effects of the work characteristics interventions on sleep quality were found (Bourbonnais et al., 2011; Bourbonnais et al., 2006; Moen et al., 2011). In a third intervention study (Wahlstedt & Edling, 1997), however, a significant positive effect of an increase in skill discretion on sleep quality was revealed, but only at the second follow-up measurement. The manipulation check in this study showed that for all other psychosocial work characteristics, the intervention did not enhance the work characteristics or the work characteristics did not have a significant effect on sleep quality.

Table 2.6 Quality evaluation of intervention studies

Reference	1	2	3	4	5	6	7	8	9
Bourbonnais et al., 2006 + 2011 [a]	••	•••	•••	•••	•••	•••	•••	••	•••
Moen et al., 2011	••	••	••	•••	•••	0	•••	••	•••
Wahlstedt & Edling, 1997	0	•••	•••	•••	•••	•••	•••	••	•••

Note: 0 = insufficient, •• = sufficient, ••• = good, 1 = control group and randomization, 2 = measuring TPs: sleep quality, 3 = measuring TPs: work characteristics, 4 = intervention content, 5 = intervention process, 6 = measures: sleep quality, 7 = measures: work characteristics 8 = non-response analysis, 9 = statistical adjustment

[a] These studies were judged as at least "sufficient" on all nine criteria and were thus considered high-quality studies

2.3.2 RESULTS (PART II: HIGH-QUALITY STUDIES)

Three longitudinal studies (Åkerstedt et al., 2012; De Lange et al., 2009; Magnusson Hanson et al., 2011) and one intervention study (Bourbonnais et al., 2011; Bourbonnais et al., 2006) (described in two different papers) could be categorized as high quality. In the first high-quality longitudinal study (Åkerstedt et al., 2012), job demands and job control were examined in relation to sleep quality (sample: 3077 Swedish employees, mixed occupation). A full-panel design was used with one time lag and measuring points five years apart. Data were analysed with logistic regression analyses. In the second high-quality longitudinal study (De Lange et al., 2009), relations between job demands, job control, and sleep quality were investigated (sample: 1136 Dutch employees, mixed occupation). An incomplete

panel design was applied with three time lags and one year between measuring points. Structural equation modelling was used to analyse the data. In the third high-quality longitudinal study (Magnusson Hanson et al., 2011), the relationship between job demands, job control (only decision authority), and social support on the one hand and sleep quality on the other hand were examined (sample: 3041 Swedish employees, mixed occupation). A full-panel design was used with one time lag and measuring points two years apart. Data were analysed with structural equation modelling. The high-quality longitudinal research contained the two studies examining both normal and reversed/reciprocal relations (De Lange et al., 2009; Magnusson Hanson et al., 2011). Thus in the next paragraph, we discuss reversed and reciprocal relations in addition to normal relations.

Regarding job demands, in two of the three high-quality longitudinal studies, a negative effect of job demands on sleep quality was revealed [i.e., higher job demands coincided with poorer sleep quality; SIC(3) = -0.67, moderately strong evidence for a negative relation] (Åkerstedt et al., 2012; De Lange et al., 2009). Moreover, in these two studies a normal relation model fitted the relationship between job demands and sleep quality best, meaning that employees who reported more job demands experiences poorer sleep quality.

Furthermore, in two of three high-quality longitudinal studies, a significant positive link between job control and sleep quality was revealed (De Lange et al., 2009; Magnusson Hanson et al., 2011). A significant positive effect of job control on sleep quality (normal relation) was revealed in one study, but no evidence for reversed or reciprocal relations (De Lange et al., 2009). In an additional study, no relations were found between job control and sleep quality [SIC(3) = 0.67, moderately strong evidence for a positive relation] (Magnusson Hanson et al., 2011).

In one high-quality longitudinal study, social support was investigated: no significant link between social support and sleep disturbances was found (Magnusson Hanson et al., 2011). This study also examined reversed and reciprocal relations and an unfavourable effect of sleep disturbances on social support was found (reversed relation), but no normal or reciprocal relation (Magnusson Hanson et al., 2011). Additionally, this study differentiated between awakening problems and sleep disturbances and a reciprocal relationship between all three job characteristics (demands, control, support) and awakening problems was found. This means that in addition to a normal relation, a reversed relation was present as well.

In the high-quality intervention study (Bourbonnais et al., 2011; Bourbonnais et al., 2006), it was attempted to influence the work characteristics job demands, job control, social support, and effort–reward imbalance by introducing an intervention team that proposed solutions to improve these work characteristics.

Subsequently, these solutions were implemented by the employees (sample: 247 experimental group and 220 control group, Canadian care providers). A pre-intervention measurement was performed right before the intervention started and two follow-up measurements were carried out (one and three years post-intervention). At the first follow-up measurement, an ANCOVA analysis showed that job demands, social support, and effort–reward imbalance significantly improved, whereas job control decreased in both groups. Moreover, no change in sleep quality was found. At the second follow-up measurement, another ANCOVA showed that all psychosocial work characteristics had significantly improved compared to the pre-intervention measure. Again, no change in sleep quality was found. To summarize, no significant effect of a change in psychosocial work characteristics on sleep quality could be established. Reversed and reciprocal relations were not examined.

2.4 DISCUSSION

Sleep is the recovery activity par excellence and of crucial importance for psychological well-being, physiological health, and performance (Åkerstedt, 2006; Åkerstedt et al., 2009). As such, it is essential to determine the main causes of poor sleep quality as to reduce them and restore good sleep quality. Based on occupational health theories, work-related stress and adverse psychosocial work characteristics are assumed to be important determinants of poor sleep quality (Åkerstedt et al., 2009; Karasek, 1979; Kompier et al., 2012). In 2006, a narrative review of mainly cross-sectional studies indeed showed that psychosocial work-related stress is closely related to impaired sleep quality (Åkerstedt, 2006). In line with this, a recent meta-analysis showed that several adverse psychosocial work characteristics (i.e., workload, role conflict, role ambiguity, organizational constraints, lack of control, and interpersonal conflict) were significantly related to poor sleep quality (Nixon, Mazzola, Bauer, Krueger, & Spector, 2011). Although insightful, these previous reviews were predominantly based on cross-sectional studies and consequently do not allow for causal inferences. The main aim of the current review paper was to render insight into the association between psychosocial work characteristics and sleep quality by reviewing longitudinal and intervention research on this topic. Sixteen longitudinal and three intervention studies could be identified, mostly studying normal relations (i.e., the effect of work on sleep quality) and only a small number of studies examined reversed relations (sleep quality → work characteristics). It is noteworthy that most longitudinal and intervention studies were conducted from 1995 onwards. This indicates that there

seems to be a growing research interest into this topic. In our review, the quality of all included studies was established by means of quality criteria regarding design, measurement quality, and appropriateness of analyses. The rationale for this is that more trust can be put in those published studies with design, measurements, and statistical analyses of sufficient or good quality. Our review showed that only one intervention and three longitudinal studies scored at least sufficient (i.e., sufficient or good) on all quality criteria.

The first research question was whether psychosocial work characteristics predict sleep quality (normal relation). Our review could only answer this research question for two psychosocial work characteristics, i.e., job demands and job control, since these were the only work characteristics that were examined in a large number of studies, including several high-quality studies. Based on high-quality longitudinal research, it can be concluded that higher job demands are associated with lower future sleep quality. The same conclusion can be drawn when we not only focus on high-quality studies, but include all longitudinal research on job demands and sleep quality. Regarding job control, both high-quality and all other longitudinal studies revealed moderately strong evidence for a positive link between job control and sleep quality. These findings confirm previous cross-sectional research on this topic and are in line with several occupational health theories [e.g., the Demand–Control Model (Karasek, 1979)] that emphasize the important role of high job demands and low job control in stress-related outcomes such as poor sleep quality.

It is thus safe to conclude that job demands and job control are linked to later sleep quality. The next question is how strong and relevant are these associations? A closer inspection of the odds ratios (*OR*) and betas (*ß*) indicates that effect sizes for demands and control were small to moderate (i.e., significant *OR* ranged from 1.24–2.05 and *ß* from -0.04–0.07; printed bold in Table 2 of Appendix A). This implies that not a very high proportion of variance in sleep quality seems to be influenced by these job characteristics. This was to be expected considering that job demands and control are only two of many factors determining sleep quality (see also Zapf et al., 1996). Other (partly related) antecedents are for instance health, lifestyle (e.g., alcohol consumption), and stressors in private life (Lallukka et al., 2010; Roehrs & Roth, 2001). Moreover, besides demands and control, also other psychosocial work characteristics determine the psychosocial profile of work and may show to be relevant predictors of sleep quality (e.g., bullying). As such, the effect size of the total psychosocial work quality may be higher than individual effect sizes of job demands and control. However, all other psychosocial work characteristics (e.g., social support, influence over decisions, organizational justice, effort–reward imbalance, role conflict, bullying and feedback)

were only examined in a limited number of (high-quality) longitudinal studies. More high-quality research is needed to explore the longitudinal relation between all individual psychosocial work characteristics and sleep quality, as well as their combined effects. When distinguishing between the longitudinal and intervention studies of our review, we can draw several conclusions. First, only very few studies examining the association between psychosocial work characteristics and sleep quality applied an intervention design. Second, most evidence for the relation between psychosocial work characteristics and sleep quality was found in longitudinal studies; the three intervention studies provided little support for an effect of work characteristics on sleep quality. Third, this lack of significant findings within intervention studies is partly due to program failures (Kristensen, 2005): the intervention in one-third of the intervention studies did not enhance all intended work characteristics (i.e., the manipulation of work characteristics was unsuccessful). Therefore, we must be cautious in drawing conclusions about a link between psychosocial work characteristics and sleep quality from existing intervention research.

The second aim of our review was to examine whether sleep quality has an effect on later psychosocial work characteristics (reversed relation). In one of the two high-quality longitudinal studies, cross-lagged modelling provided some evidence for a reversed relation between sleep disturbances and social support as well as reciprocal relations between work characteristics (i.e., job demands, job control, and social support) and awakening problems. However, as only two studies examined reversed relations: so far, research does not enable firm conclusions to be drawn on reversed or reciprocal relations. Nonetheless, reversed and reciprocal relations between psychosocial work characteristics and sleep quality are highly plausible. It may well be that work characteristics and sleep quality mutually influence each other in a circular process (De Lange et al., 2005; Kompier & Taris, 2011). Therefore, it is important to empirically substantiate different types of relations (normal, reversed and reciprocal) in future research (Kristensen & Aalen, 2013).

2.4.1 Strengths and limitations of the current review

We believe that one strength of our review is that the literature search and synthesis of evidence were both extensive and well-structured.

The added value of the current review in comparison to preceding reviews is: (i) its emphasis on both normal and reversed, across time relations (i.e., only longitudinal and intervention designs were included); (ii) its specific focus (i.e., on psychosocial work characteristics and sleep quality); (iii) its complete and up-to-date overview of longitudinal and intervention research on this topic (all relevant

research until 2012 is included); and (iv) the fact that we carefully developed two sets of quality criteria to assess quality of longitudinal and intervention research on this topic. We believe that a good quality assessment is very relevant when reviewing empirical studies, as it enables putting more trust in the findings of the most validly conducted studies. We hope that future researchers will benefit from these quality criteria and will be encouraged to continue conducting high-quality research in this area. Though we think that this study's quality criteria include the most important indicators, others could also be considered in future research (e.g., assessment of selection, attrition, performance, and detection biases).

A limitation regarding the evaluation of strength of evidence is publication bias, i.e., significant results being published more often than insignificant results. Since it is almost impossible to gather all non-published studies, our findings could represent an overestimation of the actual relation between work characteristics and sleep quality. However, as most included studies examined more than one work characteristic, non-significant results were also revealed, perhaps attenuating publication bias in our review. Another issue is that SIC scores were calculated with results based on the most advanced analysis. Studies varied in adjustment for covariates, which could possibly mean including results with crude associations but also including overly adjusted results. However, the results before and after adjustment did not differ significantly in almost any of the studies.

2.4.2 Limitations of previous research

From our review, it becomes clear that research conducted thus far has been restricted by several limitations. First, it revealed that not much longitudinal research on the relation between psychosocial work characteristics and sleep quality has been conducted, and especially high-quality longitudinal and intervention studies are scarce. The scarcity of intervention research is especially unfortunate since intervention designs provide a window of opportunity to examine normal as well as reversed relations in real-life work settings (Kristensen, 2005).

Another key issue of previous research is external validity. Most of the studies included in our review are based on convenience samples and not occupational sub-cohorts of population-based samples, which makes it more difficult to generalize results to the general working population.

Thirdly, longitudinal and diary studies assessing sleep quality with independent, objective instruments are missing. Some diary studies measuring sleep quality with independent measures, such as polysomnography or actigraphy, exist; however, these studies focus mostly on general (work) stress rather than specified psychosocial work characteristics (Åkerstedt, Kecklund, & Axelsson, 2007; Petersen, Kecklund, D'Onofrio, Nilsson, & Åkerstedt, 2013).

Another, yet related point, is the optimal time-period between measuring exposure to adverse psychosocial work characteristics and measuring outcome variables as for example poor sleep quality. One may expect poor sleep quality to occur shortly after for instance a period of high pressure at work. Therefore, longitudinal designs with only two measuring points, a very long follow-up, and time lags of several months or years may noticeably underestimate the real effects of short term work stressors. Diary study designs, which include several repeated within-person measurements over a short period of time, could be used in future research to detect possible short-term fluctuation in both work characteristics and sleep quality.

A fifth limitation it that the majority of longitudinal and intervention studies included one or more suboptimal elements: many studies applied insufficient designs (e.g., incomplete panel design; 63% of the included studies) or employed non-valid measures (sleep quality: 26%; work characteristics: 32%). These suboptimal characteristics reduce the validity and value of the study findings and make it hard to draw definite conclusions. This does not imply, however, that these studies cannot provide us with useful information. We can extract important information about which work characteristics might be more likely to have an effect on sleep quality, but more high-quality research is needed to draw definite conclusions. Another issue is that studies measured the central work characteristics job demands and job control in a different manner. Job demands refer to (high) workload and instruments usually assess job demands by measuring time pressure (Van der Doef & Maes, 1999). In some studies (using the Job Control Questionnaire), however, job demands were assessed as a combination of time pressure and role conflict. Comparing instruments that measure job demands in a different manner could cause differences in results. Likewise, the measures and operationalisations of job control varied from decision authority to skill discretion (Van der Doef & Maes, 1999). Since studies included in this review used different operationalisations of both job demands and job control, a comparison between these studies is not without complications and conclusions can only be drawn carefully.

A sixth limitation is that most high-quality prospective studies focused on the link between job demands and job control and sleep quality, but did not take into account potential underlying mechanisms such as, for example, worrying or rumination (i.e., perseverative cognition). One can reason that work stressors impact sleep quality via cognitive processes (i.e., mediate) such as perseverative cognition or physiological arousal. When one experiences stress from high workloads or little control over one's job, this might increase stressful cognitive activity at bedtime, induce physiological arousal (i.e., a biological mechanism), and consequently reduce sleep quality.

A final shortcoming of research so far is that reversed and reciprocal relations were only examined in two studies, and none of the intervention studies attempted to enhance sleep quality as an intervention to improve work evaluation and performance.

2.4.3 Implications for future research

Based on the described limitations of previous research, we make some suggestions for future research. One of our main appeals is to increase the number of high- quality longitudinal and intervention studies. Specifically, future research should include full-panel designs with several measurement points and varied lengths of time lags (diary as well as longitudinal research). This may enable researchers to better understand the potential normal, reversed, and reciprocal relations between psychosocial work characteristics and sleep quality, and to examine the possible underlying mechanisms, such as rumination and worry, as well as detecting fluctuations in both psychosocial work characteristics and sleep quality. Regarding reversed and reciprocal relations, it would be interesting to also examine whether suboptimal sleep quality influences the change in experience of psychosocial work characteristics (i.e., within-person change in perception) and/ or the actual change in the work situation (e.g., receiving less collegial support due to fatigue-related poorer work performance) (De Lange et al., 2005).

As a second recommendation, we emphasize the value of using high-quality measurement instruments when collecting future data. In previous longitudinal studies, only self-report questionnaires were used to measure work characteristics and sleep quality, and some of these questionnaires were not validated or did not validly measure the constructs of interest. We propose to apply validated measurement scales solely, for instance the Job Content Questionnaire (Karasek, 1998) or Dutch Questionnaire on the Experience and Evaluation of Work (Van Veldhoven & Meijman, 1994), to measure psychosocial work characteristics and the Jenkins Sleep Questionnaire (Jenkins, Stanton, Niemcryk, & Rose, 1988) or Karolinska Sleep Questionnaire (Kecklund & Åkerstedt, 1992) to measure sleep quality. Moreover, studies using objective sleep quality measures are rare; however, it is not impossible to collect such data. It would be of value to combine self-report measures with so-called 'independent, objective measurements of sleep parameters', such as actigraphy [i.e., SenseWear Armband (Pereira et al., 2012)] or 1-Channel EEG [ZEO-sleep manager pro (Shambroom, Fabregas, & Johnstone, 2012)]. These measures are user-friendly, unobtrusive, do not rely on retrospective assessments of sleep quality, and are especially useful in field and intervention settings (Pereira et al., 2012; Shambroom et al., 2012).

For further suggestions regarding the design, measurements and analyses of future research, we refer to the quality criteria that were developed for this review (Tables 2.2 and 2.3). In our opinion, these quality criteria constitute a valuable and practical checklist for designing future research.

2.4.4 Practical implications

High job demands and low job control are associated with poor sleep quality. Periodic organizational risk analyses of the psychosocial work environment can help to notice suboptimal combinations of job demands and job control and optimize psychosocial working conditions. A work pro le including high, but not too high, job demands in combination with sufficient job control results in challenging jobs (Karasek, 1979; Kompier, 2003) that can be expected to contribute to favourable sleep quality, from which both employees and organizations will benefit in terms of employee well-being and performance (Kompier et al., 2012).

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Chapter 3

Bidirectional relations between work-related stress, sleep quality and perseverative cognition

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ABSTRACT

In this longitudinal two-wave study, bidirectional relations between work-related stress and sleep quality were examined. Moreover, it was investigated whether perseverative cognition is a potential underlying mechanism in this association, related to both work-related stress and sleep quality. A randomly selected sample of Dutch employees received an online survey in 2012 and 2013. Of all invited employees, 877 participated in both waves. Structural equation modelling was performed to analyse the data. We found evidence for reversed relations between work-related stress and sleep quality. Specifically, when controlling for perseverative cognition, work-related stress was not directly related to subsequent sleep quality, but low sleep quality was associated with an increase in work-related stress over time. Moreover, negative bidirectional associations over time were found between perseverative cognition and sleep quality, and positive bidirectional associations were found between work-related stress and perseverative cognition. Lastly, a mediation analysis showed that perseverative cognition fully mediated the relationship between work-related stress and sleep quality. The study findings suggest that perseverative cognition could be an important underlying mechanism in the association between work-related stress and sleep quality. The bidirectionality of the studied relationships could be an indication of a vicious cycle, in which work-related stress, perseverative cognition, and sleep quality mutually influence each other over time.

3.1 INTRODUCTION

Roughly one out of three individuals in Western countries reports sleep problems (LeBlanc et al., 2009; Ohayon & Reynolds, 2009). The negative effects of poor sleep quality on health and work performance have been established in many studies (Barone & Menna-Barreto, 2011; Cappuccio et al., 2010; Rosekind et al., 2010; Swanson et al., 2011; Taylor et al., 2005; Wolk et al., 2005). Other research has focused on a wide variety of possible factors causing poor sleep quality (Taylor, Gehrman, Dautovich, Lichstein, & McCrae, 2014).

One of the potential causes of longer periods of disturbed sleep is chronic work-related stress (Åkerstedt, 2006). Levi and Levi (2000) define work-related stress as emotional, cognitive, behavioural, and physiological reactions to negative attributes of work, a state characterized by high levels of arousal and distress. Although working is inevitably associated with short-term stress-related load effects (e.g., fatigue, negative affect, elevated heart rate), these effects will cause no harm and will not disturb sleep, as long as they return to baseline levels during off-job periods. Sufficient recovery from work-related stress is jeopardized, however, when bodily stress systems (e.g., hypothalamo-pituitary-adrenocortical system, sympathetic-adrenal-medullary system) remain activated during off-job time ('sustained activation') (Meijman & Mulder, 1998). This prolonged stress-activation leads to bodily wear and tear ('allostatic load') that can eventually cause serious disease (McEwen, 1998). In line with this, recent studies show that work-related stress without sufficient recovery seems to be a serious risk factor for sleep (Åkerstedt, 2006; Åkerstedt, Fredlund, Gillberg, & Jansson, 2002; Åkerstedt, Lekander, Petersen, Kecklund, & Axelsson, 2014; Van Laethem et al., 2013).

Sleeping is at the same time one of the most crucial opportunities to recover from work stress (De Lange et al., 2009; Van Laethem et al., 2013). Sleep is essential for restoration of bodily processes (e.g., endocrine effects, glucose changes), which seem to counteract the negative impact of daily stress (Åkerstedt et al., 2009). Longitudinal research designs are needed to find more valid evidence for the assumed relationship between work-related stress and sleep quality, but until now this type of research is scarce. The current study aimed to fill this gap by using a longitudinal full-panel design (with a one-year time lag) measuring both sleep quality and work-related stress at two points in time.

The first aim of this study was to examine whether work-related stress predicts poor sleep quality. Based on previous research (Åkerstedt, 2006; Åkerstedt et al., 2009), we hypothesized that work-related stress is associated with decreased sleep quality one year later (Hypothesis 1: normal causation). Additionally, it seems plausible (De Lange et al., 2009; Van Laethem et al., 2013) that poor sleep qual-

ity is associated with work-related stress one year later. In line with the stressor creation hypothesis (Bowling & Jex, 2013; Spector et al., 2000), poor sleep quality may evoke new stressors (e.g., interpersonal conflicts due to irritation), which in turn may increase stress. Hence, we tested whether poor sleep quality is associated with increased work-related stress one year later (Hypothesis 2: reversed causation).

Next to work-related stress and sleep quality, we also included measures of work-related perseverative cognition (PC). PC is defined as "repeated or chronic activation of the cognitive representation of one or more psychological stressors" (Brosschot et al. 2006, p.114). It is believed to be a major cause of prolonged physiological activation and of impaired recovery and sleep (Åkerstedt, 2006; Greubel & Kecklund, 2011). Field research has shown that particularly work-related PC is accountable for prolonged physiological activation (Pieper et al., 2007). Work-related PC is characterized by repetitive thoughts about issues associated with work (Cropley & Zijlstra, 2011). Research has consistently shown that work-related PC is related to sleep problems (Åkerstedt et al., 2012; Cropley et al., 2006; Kompier et al., 2012). Hence, the second aim of this study was to longitudinally examine to what extent PC intervenes in the relationship between work-related stress and poor sleep quality. Building on previous research, we expected that work-related stress is associated with increased PC one year later (Hypothesis 3: normal causation), and that PC, in turn, is accountable for poorer sleep quality one year later (Hypothesis 4: normal causation). We also examined possible reversed causation, that is, poor sleep quality is associated with an increase in PC one year later (Hypothesis 5: reversed causation). Lastly, we expected that PC is related to an increase in work-related stress one year later (Hypothesis 6: reversed causation).

3.2 METHODS

3.2.1 Design and participants

This study employed a two-wave full-panel design with a time lag of 13 months. Employees who had completed the Netherlands Working Conditions Survey 2010 (NWCS; Koppes, De Vroome, Mol, Janssen, & Van den Bossche, 2011) were invited for a longitudinal follow-up study in 2012 and 2013. The NWCS is a yearly survey conducted among a large, randomly selected sample of Dutch employees. It provides insight into the quality of working life and employee health. All participants who completed the online version of the NWCS in 2010 and agreed to participate in a follow-up study (N = 5504) received an online questionnaire in October 2012 (Wave 1 in this study) and in November 2013 (Wave 2 in this study). Each wave

included two reminders (after one and three weeks, respectively). Of all invited employees, 2633 individuals participated in the first follow-up wave (response rate of 48%) and 1393 of these participated in the second follow-up wave (response rate of 53%, see Figure 3.1). Only participants who worked at least 24 hours a week on both time points were included in this study. We used this criterion because we wanted to guarantee substantial exposure to work. After applying this inclusion criterion 1106 participants remained. Next, all participants who performed night work were excluded, after which the sample consisted of 929 participants. We decided to exclude night workers since night workers have very different sleeping patterns compared to the general workforce (Åkerstedt, 2003). Fifty-two participants did not fill out one or more of the relevant scales (i.e., work-related stress, PC, sleep quality), and were therefore excluded from the analyses. To verify

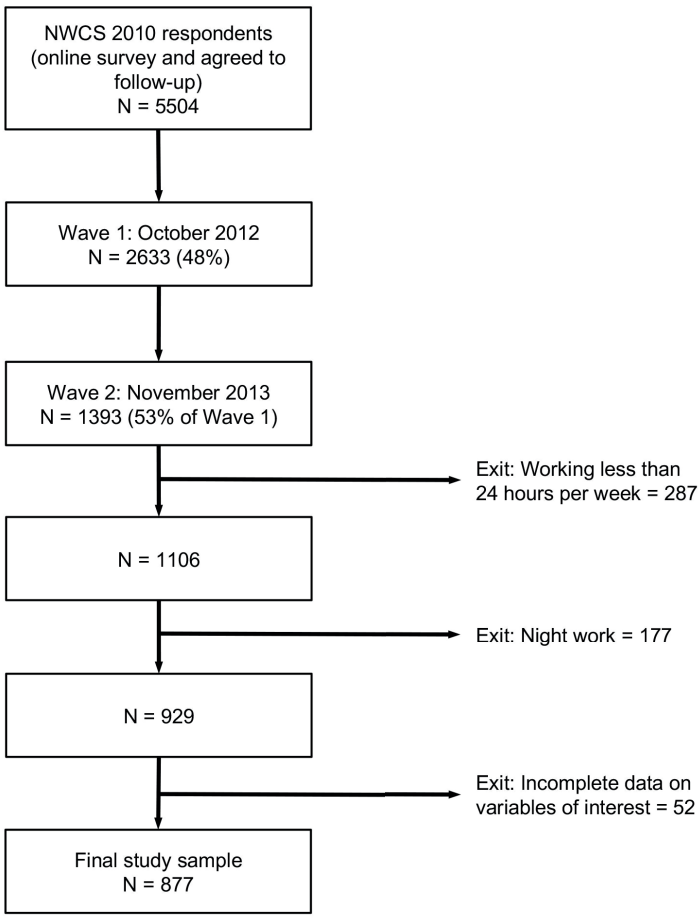

Figure 3.1 Sampling procedure and final study sample

that the missing data were randomly distributed, we performed the Little's Missing Completely at Random (MCAR) test. This test was not significant, indicating random distribution of the missing data. Consequently, it was deemed acceptable to indeed exclude all participants with missing data. The final sample consisted of 877 participants with data on both measurement points. Comparing this sample to the initial sample (N = 5504) in terms of gender, age, and educational level, differences in age (M_{final} = 44.4; SD = 10.6 vs. $M_{initial}$ = 40.0; SD = 12.2; d = 0.39) and educational level (60.9% with high education in final sample vs. 39.5% in initial sample; d = 0.44) were detected. Moreover, non-response analyses comparing the final sample to all participants from Wave 1 (N = 2633) did not reveal significant differences between respondents and non-respondents with regard to any of the background or study variables (i.e., d < 0.20). Thus, except for the background variables age and educational level, our final sample appears to be similar to the initial sample and follow-up sample, with the initial sample being representative for the Dutch working population. The majority of participants in the study sample were male, aged between 40 and 59 years, and relatively highly educated (see Table 3.1 for an overview of study sample characteristics). All participants provided informed consent.

Table 3.1 Sample characteristics

	N	%
Gender		
Men	563	64.2
Women	314	35.8
Age		
23 - 29	60	6.8
30 - 39	189	21.6
40 - 49	237	27.0
50 - 59	300	34.2
60 - 66	91	10.4
Educational level		
Low educational level	76	8.7
Moderate educational level	267	30.4
High educational level	534	60.9

3.2.2 Measures

Inspired by Elo, Leppänen, and Jahkola (2003), who developed a one-item measure to assess stress symptoms, we self-constructed the item "How much stress do you generally experience due to your work?" to measure *work-related stress* in this study. The response scale was based on the Dutch grading system, which is the standard in the Netherlands, and ranged from 1 (no stress at all) to 10 (very much stress).

Work-related perseverative cognition was assessed with three items of the Dutch Questionnaire on the Experience and Evaluation of Work (VBBA), which has been validated and is extensively used in scientific research (Van Veldhoven & Meijman, 1994; Van Veldhoven, Prins, Van der Laken, & Dijkstra, 2014). Exact wording of the

items was "When I leave my work, I continue to worry about work problems", "I can easily detach myself from my work" (reverse coded), and "During my free time, I often worry about my work". The response scale for all items was a 4-point scale (1 = never, 2 = sometimes, 3 = often, 4 = always). The scale score was determined by calculating the mean of the three items. Reliability analysis revealed Cronbach's alpha coefficients of 0.74 at Time 1 (T1) and 0.77 at Time 2 (T2).

Subjective sleep quality was assessed with the Jenkins Sleep Scale (JSS) (Jenkins et al., 1988). This scale consists of four items, which check the occurrence of the following sleep complaints during the past four weeks: (i) difficulty initiating sleep, (ii) awakening during the night, (iii) difficulty maintaining sleep including waking up too early, and (iv) non-restorative sleep. All items were scored on a 6-point scale (0 = not at all, 1= 1–3 days, 2 = 4–7 days, 3 = 8–14 days, 4 = 15–21 days, 5 = 22–28 days). The mean scale score was calculated, higher scores indicating lower sleep quality. Cronbach's alpha for the JSS was 0.78 at T1 and 0.79 at T2.

Control variables: *Gender* and *age* have been shown to be related to sleep (Lichstein, Durrence, Riedel, Taylor, & Bush, 2004; Prinz, 2004): sleep problems are more common in women and increase with age. Moreover, gender differences have also been shown regarding PC as women are more likely to ruminate than men (Broderick, 1998; Johnson & Whisman, 2013; Nolen-Hoeksema & Jackson, 2001). Therefore, all analyses were controlled for gender (1 = male, 2 = female) and age (in years). Since individuals with higher education more often hold high status jobs than individuals with lower educational level and are likely to experience more work-related stress and negative work-home spillover (Moen, Lam, Ammons, & Kelly, 2013; Schieman & Reid, 2009), *educational level* was also included as a control variable (recoded: 1 = 'low educational level', i.e., no education, primary school or lowest level of secondary school; 2 = 'moderate educational level', i.e., secondary school and intermediate vocational education; 3 = 'high educational level', i.e., higher education as for example a university degree).

3.2.3 Statistical analyses

After computing descriptive statistics and correlations, Structural Equation Modelling (SEM) was performed using LISREL version 9.1 (Jöreskog & Sörbom, 2013). Using this technique, we were able to examine the temporal relationships between work-related stress, PC, and sleep quality and thereby simultaneously test our hypotheses. All T1 and T2 variables were entered in the same model (work-related stress, sleep quality, and PC). Auto-regressions over time (e.g., paths between work-related stress at T1 and T2), 'normal causation' pathways (e.g., T1 work-related stress to T2 sleep quality), and 'reversed causation' pathways (e.g., T1 sleep quality to T2 work-related stress) were entered. Additionally, the control

variables gender, age, and educational level were added to the model as predictors of work-related stress, PC, and sleep quality at T1.

Model fit was assessed using the Adjusted Goodness of Fit Index (AGFI) and the Root Mean Square Error of Approximation (RMSEA). The Comparative Fit Index (CFI) and the Non-Normed Fit Index (NNFI) were used to indicate comparative fit. Model fit was regarded as sufficient if the AGFI, CFI and NNFI were ≥ 0.95 (Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 1999) and RMSEA was ≤ 0.07 (Steiger, 2007).

3.3 RESULTS

3.3.1 Descriptive statistics

Means, standard deviations and correlations are presented in Table 3.2. Correlations between constructs of interest were all significant and in the expected direction, e.g. a positive correlation between work-related stress and PC. Stability of the study variables over time was high with correlations ranging between 0.55 and 0.68 and standardized beta coefficients ranging between 0.46 and 0.65 (see also Figure 3.2).

Moreover, the prevalence of work-related stress, sleep quality, and PC was inspected. In our sample, the prevalence of work-related stress (score of 6 or higher on a 10-point scale) at the first measurement point (T1) was 50.1% and at the second measurement point (T2) 46.7%. About 12.6% of employees at T1 and 12.9% at T2 reported very high levels of work-related stress (score of 8 or higher).

Regarding sleep quality, the prevalence of poor sleep quality in our sample was somewhat lower compared to the prevalence of poor sleep in other study samples. Ohayon and Reynolds (2009) reviewed several European studies on sleep problems. They found that 10.9% of the general population has difficulties initiating sleep. In our sample, approximately 3.1% experienced this symptom on a regular basis. According to Ohayon and Reynolds' (2009) review, about 23.1% of individuals reported difficulties maintaining sleep, which is somewhat higher than the prevalence of this symptom in our sample (14.6%–14.9%). Moreover, in our study sample between 9.7% and 10.5% of the participants reported early morning awakenings compared to 12.3% in Ohayon and Reynolds' (2009) group. Lastly, these authors found a prevalence of 11.1% for non-refreshing sleep, whereas the prevalence was between 6.0% and 6.7% in our sample. The differences between our sample and the sample in Ohayan and Reynolds' (2009) sample are not unusual. Our sample consists of employees only (potentially a healthy sub-sample of the complete population), whereas the sample in Ohayan and Reynold' (2009)

Table 3.2 Means, standard deviations and correlations between research variables

		M	*SD*	1	2	3	4	5	6	7	8	9
1	**Gender**[a]	1.36	0.48									
2	**Age**	46.44	10.57	-.12**								
3	**Educational level (1-3)**	2.52	0.65	.03	-.18**							
4	**Work-related stress T1 (1-10)**	5.21	2.05	.01	-.11**	.11**						
5	**Work-related stress T2 (1-10)**	5.04	2.16	.03	-.09**	.12**	.55**					
6	**Sleep quality T1 (0-5)**	1.17	1.01	.11**	.07*	-.04	.27**	.24**				
7	**Sleep quality T2 (0-5)**	1.21	1.03	.09*	.06	-.01	.24**	.32**	.68**			
8	**Perseverative cognition T1 (1-4)**	2.00	0.53	-.02	-.04	.13**	.50**	.40**	.32**	.29**		
9	**Perseverative cognition T2 (1-4)**	2.06	0.54	-.00	-.06	.14**	.43**	.46**	.28**	.38**	.65**	

Note: [a] 1 = male, 2 = female, 36% ♀

* = $p < 0.05$, ** = $p < 0.01$ (two-tailed), n = 877

review is much broader, also including unemployed individuals. Moreover, sleep quality has not been measured in the same way in all reviewed studies.

Concerning work-related PC, the prevalence of moderate levels of PC (i.e., a mean score between 2 and 3 on a 4-point scale) ranged from 63.8% at T1 to 64.7% at T2. High levels of PC (i.e., a mean score of 3 or higher) were reported by 5.5% (T1) to 8.3% (T2) of the participants. When comparing these prevalences to the benchmark measures of the original PC scale (moderate PC: 51.7%; high PC: 5.0%), the latter measures are a bit lower, but still quite comparable to our population (cf. Van Veldhoven et al., 2014).

3.3.2 Temporal relations between work-related stress, PC, and sleep quality

First, we examined model fit for the complete structural equation model. The χ^2 value of the model was low and non-significant ($\chi^2 = 10.83$, df = 9, $p = 0.29$), indicating that the model fitted the data well. All other fit indices also suggested good model fit: RMSEA = 0.02, NNFI = 0.99, CFI = 0.99, AGFI = 0.99. We examined the temporal relationships between work-related stress, PC, and sleep quality and tested our hypotheses by inspecting the normal and reversed causation pathways for the hypothesized relationships. See Figure 3.2 for a visualization of the model and the standardized regression coefficients of normal and reversed structural paths.

Regarding the relation between work-related stress at T1 and sleep quality at T2, the normal causation path was non-significant ($\beta = 0.03$, $p > 0.05$) and, thus, hypothesis 1 did not receive support. The reversed causation pathway from T1 sleep quality to T2 work-related stress, however, was significant ($\beta = 0.07$, $p < 0.05$) and in support of hypothesis 2.

To examine the relation of PC with work-related stress and sleep quality, we examined the structural paths between T1 work-related stress and T2 PC and between T1 PC and T2 sleep quality. Since the normal causation pathway between work-related stress and PC ($\beta = 0.14$, $p < 0.05$), as well as the normal causation path between PC and sleep quality were significant ($\beta = 0.07$, $p < 0.05$), hypothesis 3 and hypothesis 4 were supported. Additionally, the reversed causation pathway between T1 PC and T2 work-related stress was significant ($\beta = 0.15$, $p < 0.05$), and the same was true for the reversed path between T1 sleep quality and T2 PC ($\beta = 0.07$, $p < 0.05$). These findings supported hypothesis 5 and hypothesis 6, and indicate a reciprocal relationship between work-related stress and PC on the one hand, and between PC and sleep quality on the other hand.

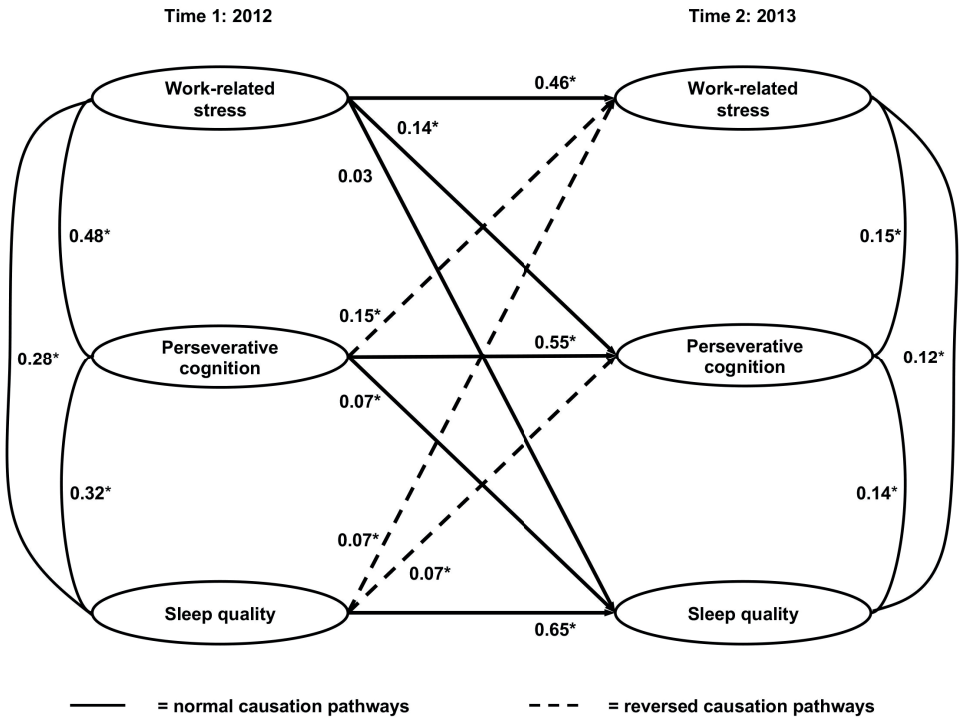

Figure 3.2 Overview of the normal and reversed paths and standardized regression coefficients (β) from the structural equation model regarding the relationships between work-related stress, sleep quality, and PC. The model is adjusted for age, gender, and educational level, but for clarity these pathways are not depicted
Note: * = $p < 0.05$

3.3.3 PC in the relationship between work-related stress and sleep quality

The 'PC hypothesis' (Brosschot, 2010; Brosschot et al., 2006) states that not so much exposure to stressors themselves, but the continued mental representation of these stressors causes prolonged physiological activation, and consequently sleep problems. The fact that we did not find a significant normal causation path between work-related stress and sleep quality in our model, in which this relationship was controlled for PC, raises the question whether PC at T1 would mediate the relationship between work-related stress at T1 and sleep quality at T2. To explore whether PC intervenes in the relationship between work-related stress and sleep quality, an exploratory mediation analysis was performed using bootstrapping. This was done using the PROCESS-macro developed by Hayes (2013). The mediation analysis was controlled for the background variables gender, age, and educational level, as well as baseline sleep quality. The PROCESS

procedure generated a 95% confidence interval (CI) for the indirect effect with 10000 iterations.

In Step 1 of the mediation model, the relationship between work-related stress and sleep quality, not controlling for the mediator, was indeed significant, b = 0.03, $t(871)$ = 2.31, $p < 0.05$. Step 2 showed that the relationship between work-related stress and the mediator PC was also significant, b = 0.11, $t(871)$ = 14.30, $p < 0.001$. Step 3 of the mediation process showed that the mediator PC, controlling for work- related stress, was related to sleep quality, b = 0.13, $t(870)$ = 2.37, $p < 0.05$. The final step of the analysis revealed that, controlling for PC, work-related stress was not a significant predictor of sleep quality, b = 0.02, $t(870)$ = 1.05, p = 0.29. The 95% confidence interval for the indirect effect (b = 0.02, SE = 0.01; 95% CI = [0.01, 0.03]) did not contain 0, indicating full mediation of PC at T1 in the relationship between work-related stress at T1 and sleep quality at T2. See Figure 3.3 for an overview of the mediation analysis.

3.4 DISCUSSION

The first aim of this study was to examine the temporal relationship between work-related stress and sleep quality. We hypothesized that work-related stress and sleep quality influence each other (H1 & H2), but only a reversed temporal relationship was found. Poor sleep quality was related to an increase in work-related

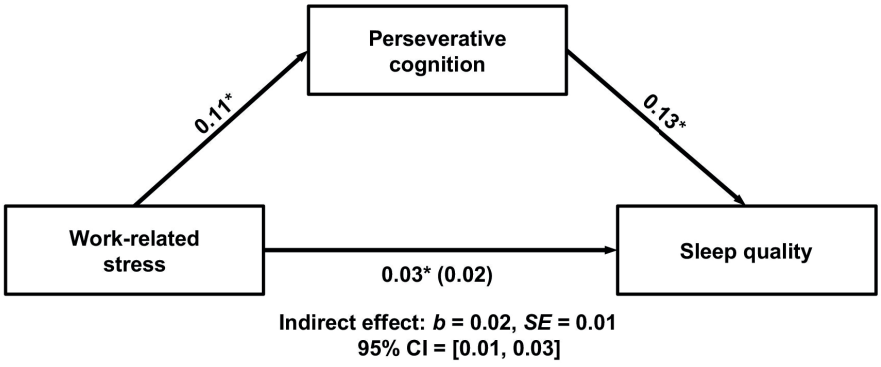

Figure 3.3 Mediation model showing the effect of T1 work-related stress on T2 sleep quality, as mediated by T1 PC. An asterisk indicates a significant result (p < .05). Unstandardized regression coefficients are shown. Under the lower path, the number outside parentheses is the total effect, and the number inside parentheses is the direct effect

Note: CI = confidence interval, SE = standard error

stress the following year, whereas higher work-related stress was not associated with a decrease in sleep quality one year later.

The second aim of this study was to determine whether perseverative cognition (PC) is related to both work-related stress and sleep quality. If so, this could indicate that PC is an underlying mechanism in the relationship between work-related stress and sleep quality. We expected reciprocal temporal relationships between work-related stress and PC, and between PC and sleep quality. Our findings indeed supported our assumptions (H3 - H6). The 'normal' causation findings (i.e., work-related stress → increased PC; PC → reduced sleep quality) are in line with the 'PC hypothesis' (Brosschot, 2010; Brosschot et al., 2006) and recent findings from a diary study on work stressors, PC, and sleep (Radstaak, Geurts, Beckers, Brosschot, & Kompier, 2014b). Our results suggest that PC may indeed be a relevant underlying mechanism in the relationship between work-related stress and sleep quality. Therefore, an exploratory mediation analysis was conducted and found that PC indeed fully mediated the normal causation relationship between work-related stress and subsequent sleep quality. These results are in agreement with the stressor creation hypothesis (Bowling & Jex, 2013; Spector et al., 2000) and lend support to previous research on work-related stress and sleep quality (De Lange et al., 2009; Magnusson Hanson et al., 2011).

We argue that the reversed effects (i.e., sleep quality → work-related stress; PC → work-related stress; sleep quality → PC) can be explained by two possible mechanisms (see also De Lange et al., 2005). The first mechanism is called 'drift mechanism' (De Lange et al., 2005; Frese, 1985; Van Hooff & Taris, 2014; Zapf et al., 1996) and explains reversed effects by attributing increased levels of work-related stress to actual changes in the work environment due to poor sleep quality. For example, sleeping poorly might negatively affect employees' work performance, which in turn increases workload and work-related stress and PC. Moreover, a recent review points out that poor sleepers have less self-control. This reduced self-control may lead to impulsivity, lowered attentional capacity, and jeopardized decision making (Pilcher, Morris, Donnelly, & Feigl, 2015). The second mechanism is coined 'gloomy perception mechanism' (De Lange et al., 2005). Employees who sleep poorly may perceive their work surroundings in a more negative way and consequently report more work-related stress. More specifically, research suggests that poor sleep may result in higher sensitivity to environmental stimuli and lead to interpretation of a stressor as more threatening or more taxing (Barber, Rupprecht, & Munz, 2014; Budnick & Barber, 2015), which in turn, may increase work-related stress directly or indirectly via PC.

In view of the 'two-way streets' (reciprocal associations), an interesting question is whether one of the causal paths (normal vs. reversed) is dominant. Inspection

of the standardized beta coefficients (β) of the normal and reversed pathways demonstrates almost identical β's for both types of pathways. It thus appears that both causal paths are equally strong.

In absolute terms, the β's are rather small and one may argue that the strength of the reciprocal associations is limited. However, in the light of longitudinal research, small β's do not necessarily mean small effects in relative terms. In SEM, changes over time (auto-regressions) are taken into account and already explain most of the variance (Van Hooff et al., 2005) as the stability factor of variables is high. Additionally, correlations between measures at the same time point (e.g., PC at T1 and work-related stress at T1) were included in all models, explaining even more of the variance. Consequently, only a small amount of variance can potentially be explained by the hypothesized reciprocal temporal relationships to begin with. Bearing this in mind, Dormann and Zapf (2002) pointed out that β's of 0.12 are already size- able effects when studying the temporal relationship between stressors and strain. Thus, even though effect sizes of the reciprocal effects in our study are restricted, these effects should not be dismissed (cf. Semmer, Zapf, & Greif, 1996).

3.4.1 Theoretical and practical implications

This study contributes to the literature by demonstrating reversed causation between work-related stress and sleep quality as well as reciprocity across time between work-related stress and PC, on the one hand, and PC and sleep quality, on the other hand (Taris & Kompier, 2014; Van Hooff & Taris, 2014). Moreover, this study revealed that PC mediated the relationship between work-related stress and sleep quality. The occurrence of both normal and reversed temporal relations might be an indication of a vicious cycle (Kompier & Taris, 2011). In this vicious cycle, work-related stress, sleep quality, and PC mutually influence each other over time. In line with this finding, we believe that normal and reversed pathways should be given equal attention in future research.

From a more practical perspective, companies need to strive for well-designed jobs. These should ideally be free from overly high levels of stressors that are known to evoke work-related stress and PC such as too high job demands, too low autonomy, and bullying (Levi & Levi, 2000). Minimized exposure to these stressors reduces work-related stress and facilitates recovery and sleep (Åkerstedt et al., 2009). In many occupational settings, however, fully eliminating job stressors to reduce work-related stress is impossible. Often, exposure to high job stressors is inevitable to some extent (e.g., in emergency rooms and high strain managerial jobs). Therefore, in addition to primary prevention efforts, organizations should also provide resources to help their employees to cope with stress and PC. Com-

panies may improve resources at work such as preventing excessive overtime work and increasing work flexibility (Beckers et al., 2008). They may also promote recovery after work and detachment from work by providing, for instance, gym memberships to facilitate exercise, and they may also provide psychological services, training in stress-management techniques and/or sleep hygiene (Budnick & Barber, 2015). Employees who make use of (some of) these resources will potentially be able to better regulate and recover from work-related stress. They may also experience better sleep quality, which, in turn, may increase motivation and productivity and will benefit the organization in the long run.

3.4.2 Limitations and suggestions for future research

This study is subject to some limitations. First, this study relies exclusively on self-report measures to measure work-related stress, PC, and sleep quality. Several problems have been associated with the use of self-report measures as, for example, social desirability or retrospection (Podsakoff & Organ, 1986). A recommendation for future studies would be to not solely rely on self-report measures, but to additionally use objective methods to assess, for instance, sleep quality (e.g., actigraphy) (Van Laethem et al., 2013). Using objective measures of sleep quality could prove particularly useful because subjective ratings of sleep quality do not always concur with more objective measures of sleep quality (Unruh et al., 2008). Thus, using a combination of subjective and objective measures to assess health-related concepts will give a more complete overview and improve the validity and generalizability of findings. A related issue is the use of a single item to measure work-related stress. Experiencing work-related stress is characterized by high levels of arousal and distress in response to adverse aspects of work (Levi & Levi, 2000). Therefore, future studies are advised to incorporate both dimensions of work-related stress (i.e., arousal and distress), and to additionally take into account sources of work-related stress as, for example, unfavourable psychosocial work characteristics. Regarding generalizability, we have to note that the sample under study had a relatively high age, was highly educated, and rather healthy as compared to the general Dutch working population ($M_{self\text{-}rated\ health}$ = 3.35, SD = 0.79 on a 5-point scale), which should be taken into account when interpreting the results of this study. Next, due to the 2-wave design we could not test an optimal mediation model with PC as intervening variable between work-related stress and sleep quality. To enable more definite conclusions on the assumed mediating role of PC, we advise future researchers to include at least three measurement points in their study. Another limitation of this study concerns the different time frames applied in the measurement of the study variables. Respondents had to indicate their average level of work-related stress and PC, not taking

a specific time frame in mind. Sleep quality, on the other hand, referred to sleep complaints over the past month. This may have had implications for the effect sizes. It is recommended that in future research identical time frames are used, thus harmonizing time frames of measured constructs. Finally, even though we made progress in determining causality, longitudinal field studies cannot provide definite conclusions in this respect, nor can they disentangle all causal processes. In most longitudinal research, one begins measuring 'at some time-point' in a developing or even already established circular process. This results in the well-known 'hen or egg' dilemma. Other research designs could shed more light on the causal reciprocal processes involved. In a natural experiment, for example, one could examine employees who initially have low levels of work-related stress, poor sleep quality, and PC, but are about to experience an increase in one of these variables. For instance, one could study individuals who will soon experience a stressful live event, such as an important exam (e.g., dissertation defence). Following these individuals during this stressful period could give more insight into causality between work-related stress, sleep quality, and PC. The same can be done in case of a natural or experimental manipulation of PC and sleep quality. A diary design, with daily measures of work-related stress, PC, and sleep quality, is a potentially strong design for such quasi-experimental field studies.

To conclude, this longitudinal study has shed light on the reciprocal relations among work-related stress, PC, and sleep quality. We found normal and reversed effects, and a mediating role of PC, with important theoretical and practical implications. In future research, different types of designs should be employed to investigate the assumed vicious cycle between work-related stress, PC, and sleep quality.

Acknowledgments

We thank William M. van der Veld of the Radboud University in Nijmegen, the Netherlands, for his statistical advice during the revision of this article.

Chapter 4

Perseverative cognition as an explanatory mechanism in the relation between job demands and sleep quality

Based on:

Van Laethem, M., Beckers, D. G. J., Geurts, S. A. E., Garefelt, J., Magnusson Hanson, L. L., & Leineweber, C. (submitted). Perseverative cognition as an explanatory mechanism between job demands and sleep quality.

ABSTRACT

In this longitudinal three-wave study, the temporal relations between job demands, work-related perseverative cognition, and sleep quality were investigated with the aim to examine (i) whether there are bidirectional associations among these variables, and (ii) whether perseverative cognition mediates the association between job demands and sleep quality. Moreover, it was examined whether individuals exposed to continuous (i.e., long-term) high job demands experience deterioration in sleep quality and an increase in work-related perseverative cognition over time. A representative sample of the Swedish working population was approached in 2010, 2012, and 2014, and 2316 respondents were included in this longitudinal full-panel survey study. Structural equation modelling was performed to analyse the temporal relations between job demands, work-related perseverative cognition, and sleep quality. Additionally, a subsample (N = 1149) consisting of individuals who reported the same level of exposure to job demands during all three waves (i.e., stable high, stable moderate, or stable low job demands) was examined in relation to perseverative cognition and sleep quality over time. Job demands, work-related perseverative cognition, and poor sleep quality (i.e., sleep disturbances and awakening problems) were positively and reciprocally related. Work-related perseverative cognition mediated the normal and reversed relations between job demands and sleep quality. Additionally, the results showed that individuals with continuous high job demands reported lower sleep quality and higher work-related perseverative cognition, compared to individuals with continuous moderate and low job demands. However, sleep quality did not decrease and work-related perseverative cognition did not increase over time for individuals experiencing stable high job demands. This longitudinal study substantiated reciprocal relations between job demands, work-related perseverative cognition, and sleep quality and supported work-related PC as underlying mechanism of the reciprocal stressor-sleep relationship. Moreover, this study provided evidence that individuals with continuous high job demands experience lower sleep quality and higher work-related perseverative cognition compared to individuals with continuous low or moderate job demands.

4.1 INTRODUCTION

Sleep problems are prevailing in modern society, with about one third of individuals from Western countries suffering from poor sleep (LeBlanc et al., 2009; Ohayon & Reynolds, 2009). Suboptimal sleep quality is associated with negative health consequences and deficient work performance (Cappuccio et al., 2010; Swanson et al., 2011; Taylor et al., 2005) and is characterized by one or more of the following symptoms (Edinger et al., 2004): (i) difficulties initiating sleep, (ii) difficulties maintaining sleep, (iii) waking up too early, or (iv) feeling non-refreshed in the morning.

Previous research has shown that (chronic) stress is an essential antecedent of poor sleep quality and that work can be an important cause of stress (Åkerstedt et al., 2009; Crawford et al., 2010; Häusser et al., 2010). A recent review suggests that job demands are among the most important work-related stressors in relation to sleep complaints (Linton et al., 2015; Van Laethem et al., 2013). Moreover, several recent studies based on the SLOSH cohort found that job demands are positively and longitudinally related to two important dimensions of poor sleep quality: sleep disturbances and non-restorative sleep (i.e., awakening problems) (Åkerstedt et al., 2015; Garefelt, Hyde, Magnusson Hanson, Westerlund, & Åkerstedt, 2016; Magnusson Hanson, Chungkham, Åkerstedt, & Westerlund, 2014). However, not all studies have provided consistent support for these findings (Magnusson Hanson et al., 2011). Knowledge about the temporal job demands-sleep relation is still limited and little is known about possible underlying mechanisms of this relationship (Linton et al., 2015; Van Laethem et al., 2015).

Work-related perseverative cognition (PC) may play an important role in the pathway from job demands to reduced sleep quality (Brosschot, 2010; Brosschot et al., 2006). PC is defined as "repeated or chronic activation of the cognitive representation of one or more psychological stressors" (Brosschot et al., 2006, p.114), with work-related PC resulting from work-related issues (Cropley & Zijlstra, 2011). Specifically, the PC hypothesis suggests that a continuous mental representation of (work) stressors may cause prolonged physiological activation, and consequently poor stress recovery and poor sleep, rather than (or in addition to) the stressors themselves (Brosschot et al., 2006). Especially work-related PC is assumed to jeopardize psycho-physiological recovery from job demands and has accordingly been associated with work-related stress(ors) and reduced sleep quality (Åkerstedt, 2006; Pieper et al., 2007; Van Laethem et al., 2015).

Only few studies have examined the direction of temporal relations between job demands, work-related PC, and sleep quality. Studies that did focus on these interrelations found indications for reciprocal relations between these concepts

(Åkerstedt et al., 2015; Garefelt et al., 2016; Van Laethem et al., 2015). Thus, in addition to normal causation relations (job demands -> PC, PC -> sleep quality), also reversed causation relations (sleep quality -> PC, PC -> job demands) were detected. This reversed causal path is explained by the 'stressor creation hypothesis' (Bowling & Jex, 2013; De Lange et al., 2005; Spector et al., 2000), which states that poor sleep quality may alter an individual's perception of their work environment and/or may foster work-related PC.

The first aim of this study was to confirm the bidirectional associations between job demands, work-related PC, and sleep quality. The present study is a follow-up study of Garefelt et al. (2016) and thus we expected to replicate the reciprocal, positive relations (i.e., both normal and reversed relations) found between job demands and poor sleep quality (both sleep disturbances and awakening problems; Hypothesis 1). Moreover, based on a previous study by Van Laethem et al. (2015), we expected that job demands are reciprocally and positively related to work-related PC (Hypothesis 2), and that work-related PC, in turn, is reciprocally and positively related to poor sleep quality (Hypothesis 3). The second aim of this study was to examine whether perseverative cognition mediates the association between job demands and sleep quality. Very few previous studies on this topic included three or more waves allowing for proper mediation analysis, and no study previously examined reciprocal mediation. We expected that work-related PC is a mediator in the reciprocal association between job demands and sleep quality (Hypothesis 4).

4.1.1 Continuous exposure to high job demands

The core assumption of Effort-Recovery theory is that after effort expenditure at work individuals are fully recovered when psycho-physiological systems have returned to baseline levels by means of psycho-physiological unwinding before the start of a new period of effort expenditure (Meijman & Mulder, 1998). However, if psycho-physiological recovery is incomplete (e.g., due to excessive overwork or prolonged preoccupation with work), one starts the next working period still feeling fatigued. As a result, one has to expend compensatory effort to perform adequately, which increases the burden on the recovery process and may lead to an accumulation of fatigue. Accordingly, Allostatic Load theory states that due to a long-term accumulation of load effects, psycho-physiological systems may start to malfunction, resulting in chronic load effects (McEwen, 1998). As sleep is undeniably the most important recovery activity (Åkerstedt et al., 2009), high job demands and inadequate recovery are expected to be associated with a decline in sleep quality. Additionally, work-related PC will likely increase when dealing with higher job demands (Åkerstedt et al., 2009). The third aim of the present

longitudinal study was to examine whether individuals suffering from *continuous* (i.e., long-term) high job demands experience a deterioration in sleep quality and an increase in work-related PC over time. We hypothesized that individuals, who experience stable high job demands, experience lower sleep quality (Hypothesis 5a) and higher work-related PC (Hypothesis 5b) compared to individuals with stable moderate or low job demands. We also expected that employees with stable high job demands show a decrease in sleep quality (Hypothesis 6a) and an increase in work-related PC (Hypothesis 6b) over time, whereas these unfavourable changes are expected to be absent among workers with stable low or moderate exposure to job demands.

4.2 METHODS

4.2.1 Study population

The study population consisted of the participants of the SLOSH (Swedish Longitudinal Occupational Survey of Health) study, a longitudinal cohort survey with a focus on the association between work organization, work environment, and health. SLOSH follows participants of the Swedish Work Environment Surveys (SWES) conducted every second year by Statistics Sweden. The SWES consist of a subsample of gainfully employed people aged 16 - 64 from the Labour Force Survey (LFS). Since the start of SLOSH in 2006, eligible SWES participants were invited every second year to respond to a postal questionnaire in two versions, one for those currently gainfully employed and one for those permanently or temporarily outside the labour force. Respondents were categorized as being in paid work if they had worked on average ≥ 30% during the past 3 months. Data collection was conducted by Statistics Sweden. Response rates were above 50% in all waves. The current paper included participants who were gainfully employed in the 2010 (N = 9132), 2012 (N = 7325), and 2014 (N = 15359) data collections. Out of the 9132 participants employed in 2010, 754 participants were not employed two years later, and 2818 people did not respond to the questionnaire in 2012, resulting in 5569 participants gainfully employed both in 2010 and 2012. Out of those, 662 participants were not in paid employment in 2014 and 1765 persons did not participate in SLOSH 2014 at all. Thus, 4079 participants were gainfully employed in all three waves. Dropout analyses were conducted, comparing the effective longitudinal sample with participants with available data at 2010, but not in the later waves. The analyses showed that the effective longitudinal sample consisted of slightly more women (57.6% vs. 54.3%, $p = .001$), somewhat younger (49.2 ± 8.7 vs. 50.2 ± 11.2; $p < .001$) and higher educated individuals ($p < .001$) com-

pared to all respondents in 2010. As the present study focused on sleep quality, respondents who worked night shifts on at least one of the waves were excluded from analyses (N = 999). The final sample consisted of 3080 participants. See Figure 4.1 for the sampling procedure. The SLOSH study has been approved by the Regional Research Ethics Board in Stockholm. Informed consent was obtained from all individual participants included in the study.

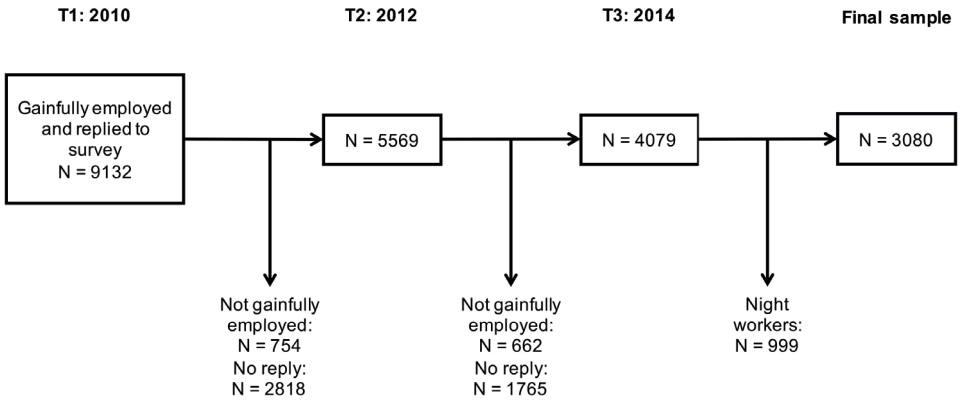

Figure 4.1 Sampling procedure and final study sample

4.2.2 Measures

We assessed two important dimensions of sleep quality. *Sleep disturbances* (reflecting lack of sleep continuity) were measured with four items (difficulty falling asleep, repeated awakenings, early awakening, disturbed sleep). *Awakening problems* (reflecting feelings of being insufficiently restored) were assessed by two items (difficulty awakening, not well-rested). All items were derived from the Karolinska Sleep Questionnaire (KSQ) (Åkerstedt et al., 2015; Åkerstedt et al., 2012; Nordin, Åkerstedt, & Nordin, 2013). Response options reached from 1 = never to 6 = always/5 times a week or more. Cronbach's alpha coefficients for disturbed sleep ranged from 0.84 to 0.85.

Job demands were measured by the Swedish version of the Demand-Control Questionnaire (DCQ) (Chungkham, Ingre, Karasek, Westerlund, & Theorell, 2013; Fransson et al., 2012; Theorell et al., 1988) and were assessed by four items (working fast, too much effort, enough time (reversed), and conflicting demands). All items had four response options (1 = never/almost never, 2 = rarely, 3 = sometimes, 4 = often). Cronbach's alpha coefficients for job demands ranged from 0.65 to 0.68. *Decision authority* was derived from the same questionnaire and was assessed with two questions (choice in how you do your work and what you do at work), and was used as a covariate in this study.

Work-related PC were measured with three items of the over-commitment scale from the effort-reward imbalance questionnaire (Leineweber et al., 2010; Siegrist et al., 2004). The items are: "Work rarely lets me go, I even think about it in the evenings"; "When I get home, I can easily relax and 'switch off' work" (reversed), and "As soon as I get up in the morning I start thinking about work problems". All items were answered on a 4-point Likert scale reaching from 1 = totally disagree to 4 = totally agree. Cronbach's alpha coefficient was 0.83 across all time points.

4.2.3 Analytic strategy

Average scores for sleep disturbances, awakening problems, job demands, work-related PC, and the covariate decision authority were computed. The longitudinal data were analysed with structural equation modelling. This type of analysis allows for path analysis in the traditional direction (i.e., normal causation: job demands -> PC -> sleep quality), but also for paths opposite to the traditional direction (i.e., reversed causation: sleep quality -> PC -> job demands) (Lockhart, MacKinnon, & Ohlrich, 2011). The sleep quality dimensions 'sleep disturbances' and 'awakening problems' were entered as separate, but correlated factors. We compared four possible models: The first model (Model 0), only included auto-regressions over time. In the next step, the 'normal causation' model (Model 1: job demands -> sleep quality, job demands -> PC, PC -> sleep quality), and the 'reversed causation' model (Model 2: sleep quality -> job demands, PC -> job demands, sleep quality -> PC) were fitted to the data, while still including the auto-regressions in each model. Finally, the reciprocal model (Model 3: job demands <-> sleep quality, job demands <-> PC, PC <-> sleep quality) was tested. Structural equation modelling was performed with the lavaan 5.20 package in R Statistical computing and graphics software (Rosseel, 2012; R Core Team, 2015). To reduce possible bias by missing data we used the full information maximum likelihood (FIML) estimation (Arbuckle, 2006). Based on the recommendations of Hu and Bentler (Hu & Bentler, 1999), model fit was assessed with the root mean square error of approximation (RMSEA) and the comparative fit index (CFI). Standardized estimates were calculated for all models and are reported here. The analysis was controlled for gender (1 = male, 2 = female), age (in years), education (1 = compulsory, 2 = 2-year upper secondary/vocational training, 3 = 3 or 4-year upper secondary, 4 = university or equivalent < 3 years,5 = university or equivalent ≥ 3 years) and the time-varying covariates shift work (0 = no shift work, 1 = shift work; night workers were already excluded) and decision authority. Indirect effects (mediated effects) were estimated by the product of coefficients method (MacKinnon, 2014). In this method, the estimate of the relation between the independent variable and the mediator is multiplied with the estimate of the relation between the mediator and

the dependent variable. Statistical significance of the effect was evaluated using the bootstrapped 95% confidence intervals with 10000 iterations. Mediation is determined when the confidence interval does not contain 0 (Zhao, Lynch, & Chen, 2010).

For the analysis concerning continuous exposure to high job demands, three subgroups were created. For each time point, mean scores on job demands were divided with a tertiary split. The tertiary split was identical on all time points. The job demands measure was recoded so that 1 indicated low job demands (cut-off score: ≤ 2.25), 2 indicated moderate job demands (cut-off score: 2.25 - 2.75), and 3 indicated high job demands (cut-off score: > 2.75). If an individual's score fell into the same demands-subgroup on all time points, this individual was categorized into a stable group (i.e.: 1-1-1 = stable low group, 2-2-2 = stable moderate group, and 3-3-3 = stable high job demands group). After creating the stable job demands groups, 488 participants (15.8% of full sample) had stable low job demands at all three time points, 277 participants (9.0% of full sample) experienced stable moderate job demands, and 384 participants (12.5% of full sample) had stable high job demands. Altogether, the stable groups (N = 1149) comprised of 37.3% of the total sample. Continuous high job demands were high in absolute terms as the cut-off for high job demands was a score between 2.8 and 4 (range: 1-4) on all time points. Next, a 3x3 repeated measures MANOVA was performed, including time as within factor (i.e., three time points), and sleep disturbances, awakening problems, and work-related PC as dependent variables. Job demands group (stable low, stable moderate, stable high) was entered as between-subject factor and all covariates were accounted for.

4.3 RESULTS

4.3.1 Descriptive statistics

The study sample consisted of slightly more female respondents than male respondents (59% female). Most respondents were ≥ 40 years of age ($M_{baseline}$ = 49.01; range: 23 - 71 years). Moreover, the majority of respondents were moderately to highly educated and did not participate in shift work. See Table 4.1 for characteristics of the full sample as well as the subsample that was used for the group analyses regarding continuous exposure to job demands. Comparing the subgroup to the full sample in terms of gender, age, educational level, and work schedule, no differences were detected (i.e., d < 0.10).

Table 4.1 Sample characteristics

	Final full-panel sample		Subsample continuous job demands	
	N	%	N	%
Gender				
Men	1259	40.9	447	38.9
Women	1821	59.1	702	61.1
Age				
23 - 29	48	1.6	13	1.1
30 - 39	430	14.0	149	13.0
40 - 49	999	32.4	366	31.9
50 - 59	1299	42.2	498	43.3
60 - 71	304	9.9	123	10.7
Educational level				
Compulsory	311	10.1	124	10.8
2-year upper secondary/vocational training	724	23.5	267	23.2
3 or 4-year upper secondary	714	23.2	263	22.9
University or equivalent < 3 years	451	14.6	169	14.7
University or equivalent ≥ 3 years	880	28.6	326	28.4
Work schedule (at T1)				
No shift work	2817	91.5	1052	91.6
Shift work	263	8.5	97	8.4

Means, standard deviations, and correlations are presented in Table 1 in Appendix B. All correlations between the main research variables were significant and in the expected direction. Stability of variables over time was high with standardized beta coefficients ranging between 0.53 and 0.69.

4.3.2 Interrelations between job demands, work-related PC, and sleep quality

Structural equation models with constrained normal and reversed pathways (i.e., pathways from T1-T2 and T2-T3 were 'forced' to be equal) did not fit the data worse than models including free pathways. Thus, only the constrained models are reported here. All structural equation models fitted the data reasonably well.

See Table 4.2 for an overview of model fit and model comparisons of all structural equation models. We performed χ^2 difference tests to compare the normal (Model 1), reversed (Model 2), and reciprocal (Model 3) models to the null model (Model 0). We found that all of these models fitted the data significantly better than the null model, which indeed implies a temporal relationship between job demands, work-related PC, and sleep quality. The reciprocal model was shown to fit the data most accurately, providing the strongest support for reciprocal relations between job demands, work-related PC, and sleep quality. See Figure 4.2 and 4.3 for the standardized regression coefficients of the forward and reversed structural paths.

Table 4.2 Model fit and comparisons for structural equation models

Model	Model Fit			Model Comparison			
	χ^2 (df)	RMSEA	CFI	Model	χ^2	Model	χ^2
Model 0	1750.43 (112)	0.069	0.923				
Model 1 Normal	1653.98 (105)	0.069	0.927	1 vs 0	96.44*		
Model 2 Reversed	1588.89 (105)	0.068	0.930	2 vs 0	161.53*		
Model 3 Reciprocal	1513.69 (98)	0.068	0.933	3 vs 0	236.73*	3 vs 2	75.20*

Note: * = $p < 0.05$

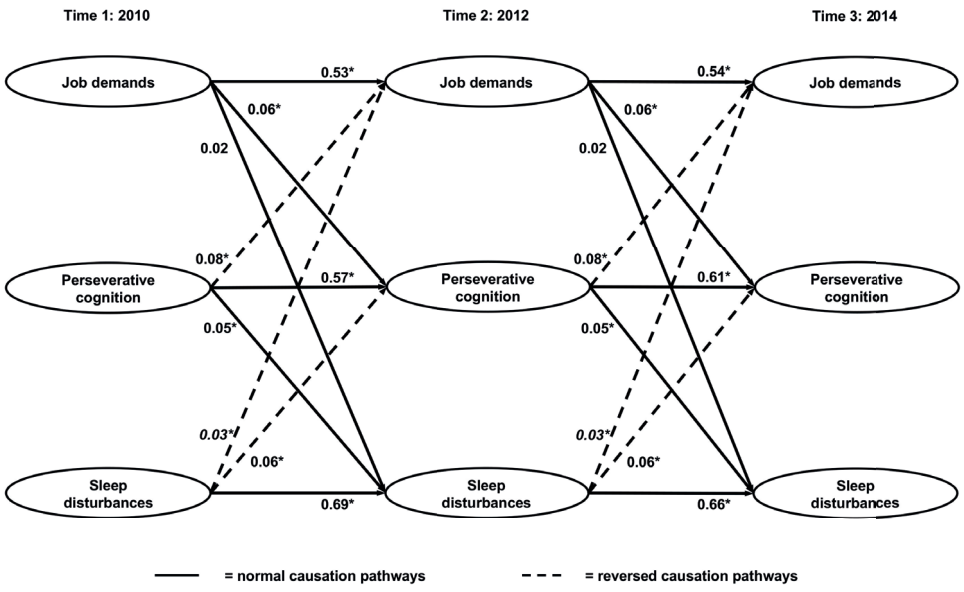

Figure 4.2 Overview of the normal and reversed pathways and standardized regression coefficients (β). The model is adjusted for age, gender, educational level, work schedule, and decision authority, but for clarity these pathways are not depicted
Note: * = $p < 0.05$

Our results regarding the direct, across-wave (T1-T2, T2-T3) relationship between job demands on the one hand, and sleep disturbances and awakening problems on the other hand, while not yet including work-related PC, replicated the reciprocal, positive relations found by Garefelt et al. (2016) (see Figure 1 in Appendix B for a visual representation of the relationships and standardized regression coefficients). As soon as work-related PC was included in the model, however, the across-wave (T1-T2, T2-T3), reciprocal relations between job demands and disturbed sleep disappeared and only near-significant, reversed relations from disturbed sleep to job demands prevailed. The positive, reciprocal relations between job demands and awakening problems remained unchanged. All normal and reversed relations between job demands and both sleep quality dimensions from T1 to T3 (i.e., across four years) were insignificant.

Relations of job demands with work-related PC were positive and reciprocal, which indicates that job demands are not only related to subsequent work-related PC, but that work-related PC are also related to subsequent higher experience of job demands. The normal causation and reversed causation pathways were all revealed to be significant. Work-related PC, in turn, was positively and reciprocally related to *sleep disturbances* and *awakening problems* as all normal and

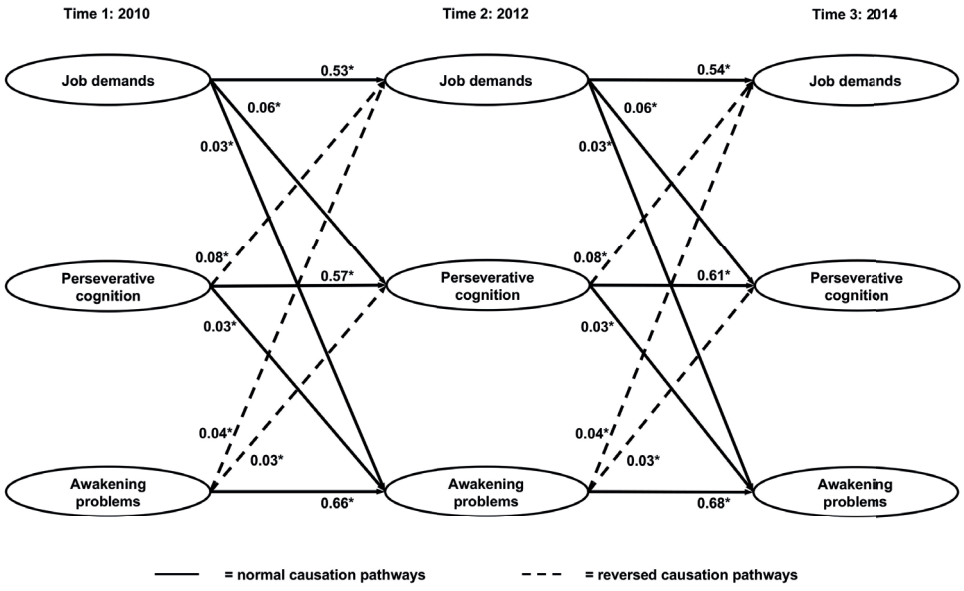

Figure 4.3 Overview of the normal and reversed pathways and standardized regression coefficients (β). The model is adjusted for age, gender, educational level, work schedule, and decision authority, but for clarity these pathways are not depicted
Note: * = $p < 0.05$

reversed causation pathways were significant. See Figure 4.2 for an overview of relationships concerning sleep disturbances and Figure 4.3 for all relationships concerning awakening problems. Please note that all relations concerning sleep disturbances and awakening problems were entered in the same model, but for clarity reasons are shown in two separate figures.

Since all main effects (i.e., direct, across-wave relations between job demands and both sleep quality dimensions, relations between job demands and work-related PC, and relations between work-related PC and both sleep quality dimensions) were reciprocal, mediation through work-related PC seemed plausible. As requirements for mediation were fulfilled, we performed a mediation analysis to test whether work-related PC acted as a mediator in between job demands on the one hand and sleep disturbances and awakening problems on the other hand. Since all relations were bidirectional, we also tested reversed mediation effects, in which sleep disturbances and awakening problems affect job demands via work-related PC. The confidence interval of the indirect effect from job demands to sleep disturbances via work-related PC did not contain 0. Therefore, work-related PC did act as a mediator in the normal pathway between job demands and sleep disturbances and accounted for approximately 17% of this relation. Work-related PC was also a mediator in the reversed pathway from sleep disturbances to job demands and mediated about 63% of this association. Lastly, work-related PC was a mediator in the normal and reversed relations between job demands and awakening problems. Work-related PC mediated approximately 13% of the normal pathway from job demands to awakening problems and fully mediated the reversed pathway from awakening problems to job demands. None of the total effects (i.e., the sum of the direct and indirect effect) were significant, which may be due to the insignificant direct effects (T1-T3) between job demands and both sleep quality dimensions. See Table 4.3 for an overview of all indirect (i.e., the amount of mediation) and total effects as well as standardized estimates.

4.3.3 Continuous exposure to high job demands

We performed a repeated measures MANOVA to examine whether individuals exposed to continuous high job demands experience a deterioration in sleep quality and an increase in work-related PC over time. No significant multivariate interaction effect of group and time was revealed ($F(12, 6606) = 1.67$, $p = .07$, $\eta_p^2 = .003$). Neither was the multivariate within-subjects main effect significant, indicating that the dependent variables (i.e., sleep disturbances, awakening problems, work-related PC) did not change over time ($F(6, 4402) = 1.46$, $p = .18$, $\eta_p^2 = .002$). However, the between-subjects main effect was significant, showing that the

Table 4.3 Indirect and total effects of job demands on sleep disturbances and awakening problems via work-related PC and the reversed effects

Direction of effect	Type of effect	Standardized estimate	Unstandardized estimate (CI)	
Job demands -> PC -> sleep disturbances	Indirect	0.003*	0.005*	(0.003 - 0.008)
Job demands -> sleep disturbances	Total	0.018	0.034	(-0.023 - 0.092)
Sleep disturbances -> PC -> job demands	Indirect	0.005*	0.003*	(0.001 - 0.004)
Sleep disturbances -> job demands	Total	-0.008	-0.004	(-0.025 - 0.016)
Job demands -> PC -> awakening problems	Indirect	0.002*	0.004*	(0.001 - 0.007)
Job demands -> awakening problems	Total	0.016	0.031	(-0.029 - 0.093)
Awakening problems -> PC -> job demands	Indirect	0.002*	0.004*	(0.001 - 0.007)
Awakening problems -> job demands	Total	-0.002	0.002	(-0.019 - 0.023)

Note: CI = confidence interval, indirect effect = amount of mediation, total effect = sum of indirect and direct effect

stable groups significantly and consistently differed from each other ($F(6, 2200) = 73.74$, $p < .001$, $\eta_p^2 = .17$).

Univariate analyses of between-subjects effects revealed that the stable low, stable moderate, and stable high groups differed from each other for disturbed sleep, awakening problems, and work-related PC (disturbed sleep: $F(2, 1101) = 75.72$, $p < .001$, $\eta_p^2 = .12$; awakening problems: $F(2, 1101) = 56.49$, $p < .001$, $\eta_p^2 = .09$; work-related PC: $F(2, 1101) = 263.47$, $p < .001$, $\eta_p^2 = .32$). Pairwise comparisons with Bonferroni correction supported these findings. Respondents in the stable high job demands group reported highest scores on sleep disturbances, awakening problems, and work-related PC. Respondents in the stable moderate and stable low job demands group reported moderate and lowest scores on sleep disturbances, awakening problems, and work-related PC, respectively. The three job demands groups all differed significantly on sleep disturbances, awakening problems, and work-related PC on all time points. An overview of group effects are presented in Figure 4.4.

4.4 DISCUSSION

4.4.1 Job demands, work-related PC, and sleep quality

The first goal of this longitudinal three-wave study was to examine the interrelations between job demands, work-related PC, and sleep quality. Results revealed reciprocal, temporal relations between job demands on the one hand and sleep disturbances and awakening problems on the other hand. These findings cor-

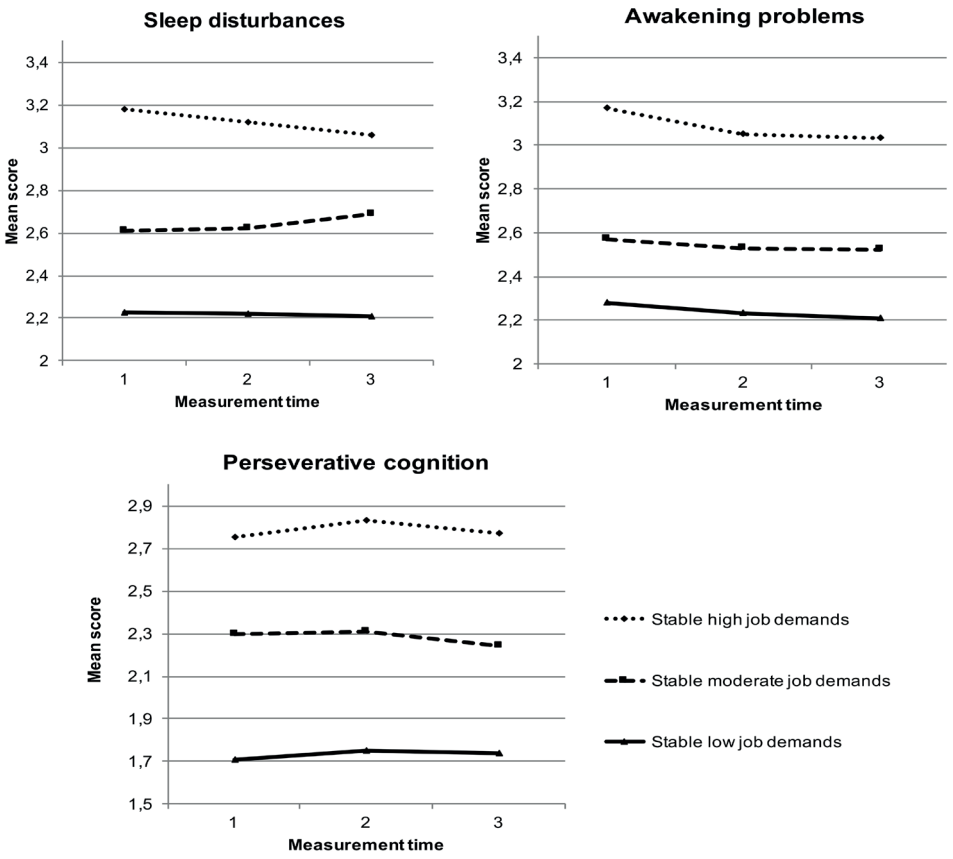

Figure 4.4 Overview of group effects for stable low, stable moderate, and stable high job demands on sleep disturbances, awakening problems, and work-related PC

respond with previous research, mostly based on the same cohort, which also found reciprocal relations (Åkerstedt et al., 2015; Garefelt et al., 2016) and supports hypothesis 1. It is noteworthy that the normal prospective relation from job demands to sleep disturbances disappeared when including work-related PC in the measurement model. Previous research has suggested that work-related PC may mediate the stress-sleep relationship (Van Laethem et al., 2015), which may explain the slightly different findings when including work-related PC in model.

Job demands and work-related PC were positively and reciprocally related over time. Thus, job demands were related to work-related PC two years later, and work-related PC was related to subsequent job demands. Additionally, positive and reciprocal relations between work-related PC and both sleep quality dimensions (i.e., sleep disturbances and awakening problems) were revealed. Work-

related PC was related to future sleep disturbances and awakening problems, which were, in turn, related to subsequent work-related PC. The results regarding positive, reciprocal relations between job demands and work-related PC on the one hand, and work-related PC and sleep quality on the other hand, are in line with a previous study (Van Laethem et al., 2015) and support hypotheses 2 and 3. Moreover, the findings underline the relevance of examining work-related PC as promising mediator in the association between job demands and sleep quality.

The mediation analyses indeed showed that work-related PC did act as a mediator in the prospective association between job demands and sleep quality (i.e., sleep disturbances and awakening problems), which is in line with the PC hypothesis (Brosschot, 2010; Brosschot et al., 2006) and supports hypothesis 4. The PC hypothesis states that a continuous mental representation of stressors may cause prolonged physiological activation, and consequently poor sleep quality, rather than (or in addition to) the stressors themselves. Job demands at T1 lead to an increase in work-related PC at T2, which in turn caused an increase in sleep disturbances and awakening problems at T3. However, the reverse was also true: sleep disturbances and awakening problems at T1 were associated with increased work-related PC at T2, which in turn, lead to increased job demands at T1. The finding that work-related PC served as a mediator in the reversed relation between sleep quality and job demands extends the PC hypothesis and supports the stressor creation hypothesis (Bowling & Jex, 2013; De Lange et al., 2005; Spector et al., 2000), which suggests that poor sleep may lead to an increase in (perceived) stressors. Indeed, *actual* job demands may increase in response to poor sleep, for instance, because one has to do certain tasks over again as a result of daytime sleepiness and low performance. Alternatively, one may be less energetic due to fatigue and consequently may *perceive* the same demands as being higher.

4.4.2 Continuous exposure to job demands

To study continuous exposure to job demands over time, we examined a subgroup of the initial sample with stable job demands across all time points, i.e., stable high, stable moderate, or stable low job demands for (at least) four years. The second objective of this study was to examine whether continuous high job demands lead to decreased sleep quality and increased work-related PC. In line with our hypotheses 5a and 5b and with Effort-Recovery theory (Meijman & Mulder, 1998), results showed that individuals with continuous high job demands had lower sleep quality (i.e., more sleep disturbances and awakening problems) and higher work-related PC, compared to individuals with continuous moderate and low job demands. However, contrary to our hypotheses 6a and 6b and not in line

with Allostatic Load theory (McEwen, 1998), sleep quality did not decrease and work-related PC did not increase over time for individuals experiencing stable high job demands. This finding suggests that most respondents with continuous high job demands experienced already high job demands before entering the study and the accumulating effects of long-term job demands may have reached their maximum. Possibly, after several years of high job demands, negative effects may cease to increase and remain constant.

4.4.3 Strengths, limitations and suggestions for future research

The present study has several assets. First, this study has a longitudinal full-panel design, which allows for drawing, albeit cautious, conclusions about temporal precedence of variables. Moreover, the three-wave longitudinal design permitted us to perform a proper mediation analyses. Another strength is the attention given to reciprocal relations instead of only focusing on the traditional direction of causality (i.e., normal causation). A final asset is the investigation of work-related PC as a crucial underlying mechanism of the stress-sleep relationship.

Nonetheless, the present study has some limitations, which need to be taken into account when interpreting the results. A first issue is the exclusive use of self-report measures to assess job demands, work-related PC, and sleep quality. The use of self-report measures has been associated with several problems such as social desirability or retrospection (Podsakoff & Organ, 1986). Spector (2006), however, has argued that these issues may not be as problematic as previously believed, for instance because mono-method correlations among study variables are often not higher than multi-method correlations. Another limitation of this study is the time lag of two years between waves, which appears to be rather long for assessing work-related PC. No consensus exists regarding an optimal time lag when measuring the association between sleep and work-related factors. Therefore, future studies may perform studies with varying time lags (e.g., from short time lags of one day to longer time lags of two or three years). Especially regarding PC, studies with shorter (day-to-day or week-to-week) time lags are relevant, as apart from stable trait-levels of PC, within-person variance (state-levels of PC) is plausible and interesting to examine. Moreover, given the time lag of two years used in the present study we cannot be certain whether the stable job demands groups were exposed to stable demands during the two years between measurements, or whether job demands fluctuated in between. However, the high auto-correlations strongly suggest that the stable groups were indeed exposed to overall stable job demands. As is often the case in longitudinal research, effect sizes were rather small (β's ranging from .03 to .08). However,

small effect sizes do not imply small effects in relative terms. Changes over time within the study variables are controlled for in structural equation modelling and explain a large part of the variance (Van Hooff et al., 2005). Moreover, job demands and work-related PC are only a few of many factors that have an impact on sleep quality (see Zapf et al., 1996). Other important causes of poor sleep quality are, for example, health, stressors in private life, and alcohol use (Lallukka et al., 2010; Roehrs & Roth, 2001). Consequently, although our study reports small effect sizes in absolute terms, these effects should not be underestimated. A final limitation is that even though this study sheds more light on causality of relations, longitudinal field studies cannot unravel all causal processes. Consequently, other research designs, as for instance experimental designs, may be used to provide more insight into causality.

4.4.4 Practical implications

Knowledge of underlying mechanisms of the stress-sleep relationship may benefit employers and employees alike. Sleep problems and other health issues stemming from continuous high job demands and a preoccupation with work may be prevented by providing employees with sufficient time to recover from high work load and consequently decreasing work-related PC, e.g., by means of sufficient work breaks during the workday or more control over work schedules (aiding recovery opportunities after work). Sufficient recovery opportunities and limiting exposure to very high job stressors can prevent a vicious cycle among work stressors, PC, and sleep problems, in the long term aiding both employee health as well as performance. Also, offering relaxation training could be a way to decrease employees' PC. Finally, as we found reciprocal effects in this study, it is important to acknowledge that sleep quality may be a valuable point of attack. For instance, promoting good sleep hygiene may help in preventing sleep problems, and thus also reduce job demands and work-related PC.

To conclude, the present longitudinal study provided more insight into reciprocity of relations between job demands, work-related PC, and sleep quality. Additionally, the role of work-related PC as an underlying mechanism of the stressor-sleep relationship was strengthened. Lastly, this study provided evidence that individuals with continuous high job demands experience lower sleep quality and higher work-related PC. Our findings give reason to continue focusing on PC in future research on work stress and sleep.

Acknowledgements

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Chapter 5

Stress, fatigue and sleep quality leading up to and following a stressful life event

Appeared as:

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ABSTRACT

This study aims to examine (a) the time course of stress, fatigue, and sleep quality among PhD students awaiting a stressful event and (b) whether daily anticipation of this event influences day-level stress, fatigue, and sleep quality. Forty-four PhD students completed evening and morning questionnaires on eight days from one month before their dissertation defence until one month thereafter. Results showed increased stress leading up to the defence, while fatigue and sleep quality remained unchanged. Comparing the night before the defence with the night after, stress rapidly decreased, whereas fatigue and sleep quality increased. Following the defence, stress and sleep quality remained stable, whereas fatigue declined. Stress one month before the defence was higher than one month thereafter. Regarding day-level relations, stress was adversely affected by negative anticipation and favourably by positive outcome expectancy, whereas positive anticipation had no influence. Positive outcome expectancy was an important predictor of improved sleep quality. We conclude that stress may be elevated long before a stressful event takes place but that one can recover rather quickly from temporary stress. Positive outcome expectancy of a stressful event may be an important predictor of reduced day-level stress and improved day-level sleep quality leading up to a stressful event.

5.1 INTRODUCTION

In modern work, highly demanding and stressful work situations have become common (cf. Hooftman, Mars, Janssen, de Vroome, & van den Bossche, 2014). Work-related stressors contribute to an individual's stress level and can lead to unfavourable health consequences (Åkerstedt, 2006; Bültmann, Kant, Schröer, & Kasl, 2002; Kristensen et al., 1998; Maslach, 1993). Fostering sufficient recovery and decreasing unfavourable outcomes of incomplete recovery (e.g., fatigue) are vital to uphold health and well-being in high stress work environments. Sleep quality may play an important role, as sleep quality is known as one of the most important recovery mechanisms (Rook & Zijlstra, 2006).

Currently, little is known about the development of stress, fatigue, and sleep quality leading up to and following a stressful event. Moreover, research on factors that might influence the time course of stress, fatigue, and recovery is scarce. The present study uses the PhD dissertation defence as a highly stressful (work-related) life event to examine the time course of stress, fatigue, and sleep quality leading up to and following this event, and to explore essential factors (i.e. anticipatory cognitions) that predict stress, fatigue, and sleep quality on the day level.

5.1.1 Stress

Stress can be defined as a subjective and physiological state characterized by a combination of displeasure and high arousal (Kristensen et al., 1998). Long-term stress has harmful effects on an individual's mental and physical health (Meijman & Mulder, 1998; Verkuil et al., 2010). Recent evidence suggests that physiological activity that is already present before the stressor presents itself or that prolongs after the stressful event has ended is more predictive of ill health than the acute stress response itself (Brosschot et al., 2006; Geurts et al., 2014). In other words, physiological activity in response to a stressor will primarily harm health if it exists and persists over a longer period of time, without sufficient day-to-day physiological and mental recovery from stress.

5.1.2 Recovery and fatigue

Recovery from stress implies a period of recuperation after a stressful event or a stressful work situation (e.g., high work demands, interpersonal conflicts) enabling energy to be restored and the psychophysiological stress response to wear off (Meijman & Mulder, 1998). According to Meijman and Mulder's (1998) Effort-Recovery theory, normal load reactions (e.g., fatigue and elevated heart rate) result from expending effort and dealing with high demands (e.g., at work). Once these

stressors are absent, as, for example, during free evenings, or weekends, those load reactions can return to baseline levels. Fatigue is an important psychological indicator of the degree of recovery and represents a proxy of failed recovery (Sonnentag & Geurts, 2009). Fatigue refers to the lack of desire (i.e., motivation) and ability to continue with one's activities and is characterized by tiredness, exhaustion, and low arousal (Demerouti, Bakker, Geurts, & Taris, 2009; Hockey, 2013; Sonnentag & Geurts, 2009). Fatigue has been related to many negative outcomes as, for instance, increases in accidents, elevated blood pressure, and ill health in general (Åkerstedt, 2000; Bültmann, Kant, Van Amelsvoort, Van den Brandt, & Kasl, 2001; Querstret & Cropley, 2012).

To fully recover and erase feelings of fatigue and stress, the interval in-between effort expenditure or stressor exposure has to be sufficiently long. If recovery is incomplete and psycho-physiological systems have not returned to baseline levels before the next stressful or taxing period, load effects will accumulate and may result in chronic stress and exhaustion (Geurts & Sonnentag, 2006).

5.1.3 Sleep quality

Sleep is the most powerful recovery opportunity from daily stress (Rook & Zijlstra, 2006). It restores bodily processes that counteract the negative impact of daily stress on well-being and health (Åkerstedt et al., 2009). The extent to which the effects of stress can be alleviated by sleep depends in part on sleep quality, which refers to the experience of sleep in terms of sleep continuity. Nowadays, disrupted sleep (i.e., low sleep quality) is a well-known problem: 30-48% of the general population experience insomnia symptoms (i.e., problems falling asleep, maintaining sleep, or waking up too early; LeBlanc et al., 2009; Ohayon & Reynolds, 2009). Especially during periods of high stress, sleep quality appears to be reduced (Zunhammer, Eichhammer, & Busch, 2014). Experiencing chronic sleep difficulties, and, as such, chronic insufficient recovery, may cause serious health problems, such as depression and cardiovascular disease (Taylor et al., 2005; Wolk et al., 2005). Such findings support the idea that favourable sleep quality is crucial to preserve long-term health by means of psychophysiological recovery from stress. Yet, at the same time, stress may counteract good sleep quality, because of physiological and cognitive arousal (Åkerstedt et al., 2009). To arrive at a better understanding of the time course of sleep quality in face of a stressful event, it is relevant to examine the development and maintenance of sleep quality leading up to and following such an event.

5.1.4 Relations between stress, fatigue, and sleep quality

Stress, fatigue, and sleep quality are all relevant concepts in Effort-Recovery theory (Meijman & Mulder, 1998) and previous research has shown that they are all related to recovery: stress and fatigue in terms of affect and activation (i.e., arousal), and sleep quality with regard to behaviour.

Stress and fatigue are both inversely related to recovery state. Research has shown that stress and fatigue are positively correlated (Kocalevent, Hinz, Brähler, & Klapp, 2011) but both concepts can be positioned within different quadrants of the circumplex model of affect (Posner, Russell, & Peterson, 2005), in which high-low affect represents one axis and high-low arousal represents another axis. Stress is characterized by high arousal and high negative affect, whereas fatigue is characterized by low arousal and low positive affect. Stress and fatigue have in common that they are both functional in the short term but are dysfunctional and harmful for health in the long term. Regarding the relationship between stress and sleep quality, several reviews have shown that stress and sleep quality are negatively associated with each other, in both cross-sectional and longitudinal research (Åkerstedt, 2006; Linton et al., 2015; Van Laethem et al., 2013). Furthermore, research has demonstrated that fatigue and sleep quality are positively related (Philip et al., 2005). Even though a considerable amount of research has focused on the interrelations between stress, fatigue, and sleep quality, little research has focused on the development of stress, fatigue, and sleep quality over time in anticipation of a stressful event.

5.1.5 Anticipation of a stressful event

The prolonged activation model (Brosschot, Pieper, & Thayer, 2005) suggests that next to stressors itself, cognitive apprehension or anticipation of a stressor can lead to stress-related physiological activity, insufficient recovery and ill health. We distinguish three forms of anticipation: positive anticipation, negative anticipation, and positive outcome expectancy. First, research has shown that positive feelings toward an upcoming event (i.e., positive anticipation) may be favourable for recovery and protect against stress-related disease (Ong, Bergeman, Bisconti, & Wallace, 2006; Papousek et al., 2010; Tugade & Fredrickson, 2004). A second form of anticipation is negative anticipation. Research demonstrated that being preoccupied with work in a negative way (i.e., negative anticipation of a stressful work situation) has a negative impact on fatigue as well as subjective and objective sleep quality (Åkerstedt et al., 2004; Kecklund & Åkerstedt, 2004). Even though an actual stressor is not present, the negative cognitive representation of the stressor may cause stress to occur or to persist, which hampers recovery from stress. Although negative anticipation and stress may seem similar at first sight,

we believe that negative anticipation is substantially different from stress. The definition of stress mentioned earlier (Kristensen et al., 1998) suggests that stress is a concept with a large affective component. Although negative anticipation also has affective components, it is more cognitive in nature and closely related to mental preoccupation with a stressor or stressful event. A last form of anticipation is positive outcome expectancy. A pessimistic expectancy about the outcome of a future event (i.e., low positive outcome expectancy) has been associated with adverse consequences and ill-health (Rief et al., 2015), however, mainly in clinical settings.

Thus, previous research suggests that the type of anticipation of a stressor or stressful situation may be vital to stress and recovery indicators and activities, such as fatigue and sleep quality. Additionally, it is interesting to examine whether anticipation leading up to a stressful event influences stress, fatigue, and sleep quality on the day-level. Prior research has largely been cross-sectional (cf. Van Laethem et al., 2013) or has used a longitudinal design (e.g., Kecklund & Åkerstedt, 2004). The present study hypothesizes that anticipation leading up to a stressful event influences stress, fatigue, and sleep quality on the day level.

5.1.6 The present study

While ample research has focused on the interrelations between stress, fatigue, and sleep quality, little research has focused on the time course of stress, fatigue, and sleep quality leading up to and following a stressful work-related event. The goal of the current diary study was to expand the literature by examining the time course of these factors in relation to a significant event. The second goal concerned day-level anticipation of a stressful event and its influence on daily stress, fatigue, and sleep quality. We chose to investigate these concepts by following individuals preparing for - and unwinding after - a highly stressful event: young scientists awaiting their public PhD dissertation defence. In a previous study, the PhD dissertation defence has been examined as a real-life stressor that is anticipated over a longer period (Van Doornen & Van Blokland, 1992), in contrast to acute stressful situations produced in a laboratory setting. Physiological stress levels on the day of the dissertation defence were increased compared to a regular control day, supporting the assumption that the dissertation defence is a real-life stressor resulting in stress.

Based on Effort-Recovery-theory (Meijman & Mulder, 1998) and the previous study by Van Doornen and Van Blokland (1992), we expected stress to increase leading up to the defence and to decrease following the defence before slowly increasing again (Hypothesis 1). Furthermore, building on the assumption that motivation to perform well is high, we expected fatigue to be suppressed (Hockey,

2013; Hopstaken, Van der Linden, Bakker, & Kompier, 2015; Oosterholt, Maes, Van der Linden, Verbraak, & Kompier, 2014) and as such hypothesized fatigue to stay rather stable before the defence (Hypothesis 2). As motivation will disappear after the defence, we expected a steep increase in fatigue following the defence. Thereafter, we expected fatigue levels to slowly decrease again. Moreover, as we expected stress to increase leading up to the defence, we concurrently hypothesized sleep quality to decrease leading up to the defence (Hypothesis 3; cf. Zunhammer et al., 2014). Also, in accordance with the anticipated increase in stress, we expected positive anticipation and positive outcome expectancy to decrease and negative anticipation to increase before the defence (Hypothesis 4). Finally, drawing from the prolonged activation model (Brosschot et al., 2005) and based on previous research of day-level relations between anticipation and recovery outcomes (e.g., Kecklund & Åkerstedt, 2004), we expected positive anticipation, negative anticipation, and positive outcome expectancy to be related to stress, fatigue, and sleep quality on the day level. More specifically, we hypothesized high levels of daily positive anticipation and positive outcome expectancy as well as low negative anticipation to be related to lower day-level stress (Hypothesis 5a) and fatigue (Hypothesis 5b) in addition to higher day-level sleep quality (Hypothesis 5c).

5.2 METHODS

5.2.1 Procedure and design

In the Netherlands, PhD students have to publicly defend their dissertation in front of a corona of professors as well as a large audience of family, friends, and colleagues. Only then they can officially graduate and receive their PhD degree. The dissertation defence lasts for one hour: during the first ten minutes, students give a presentation introducing their PhD thesis to the audience. In the remaining 50 minutes, the professors in the corona ask the PhD student questions about the PhD thesis. This event is generally recognized as being extremely stressful (Van Doornen & Van Blokland, 1992). Moreover, the dissertation defence can be considered a situation of low control, with a high social evaluative component, and ideally, a peak performance is achieved.

For each participant, the present study took place during a time span of eight weeks, starting four weeks before the dissertation defence and ending four weeks afterwards. Four measurements were administered before the dissertation defence: four weeks (Pre 1), one week (Pre 2), three days (Pre 3), and one day (Pre 4) before the dissertation defence. Similarly, post measurements were one

day (Post 1), three days (Post 2), one week (Post 3), and four weeks (Post 4) after the dissertation defence. At the beginning of the study, participants were given detailed information about the procedure and were asked to provide informed consent. Moreover, each participant received a schedule of his or her personal measurement occasions during the eight-week period.

On the first day of measurement, each participant was asked to fill in a general questionnaire regarding demographic information, psychosocial work characteristics (i.e., average level of job demands, job control), general stress and fatigue levels, and overall sleep quality. On all days of measurement, participants received an e-mail with a link to a digital diary at around 7 p.m. and another diary the following morning at around 7 a.m.. We asked respondents to fill in the evening diary at bedtime and the morning diary shortly after awaking. In the evening diary, we measured momentary stress and momentary fatigue. Sleep quality of the previous night was assessed in the morning diary. Also, positive anticipation, negative anticipation, and positive outcome expectancy regarding the defence during the past evening and/or night were assessed in the morning to prevent answers regarding anticipation to interfere with subsequent sleep. Participants could choose to receive text messages as reminders. Text messages were sent as requested: in the evening, morning or on both occasions. See Figure 5.1 for a visualization of measurement timing and design.

To promote participation and reduce missing data, we raffled two lottery prizes among participants. The winners could choose between an iPad mini and a Centre Parcs gift card matching the value of the iPad mini. Participants who returned all questionnaires had a higher chance of winning than participants with missing data. This study was approved by the Ethics Committee of the Faculty of Social Sciences at the university involved.

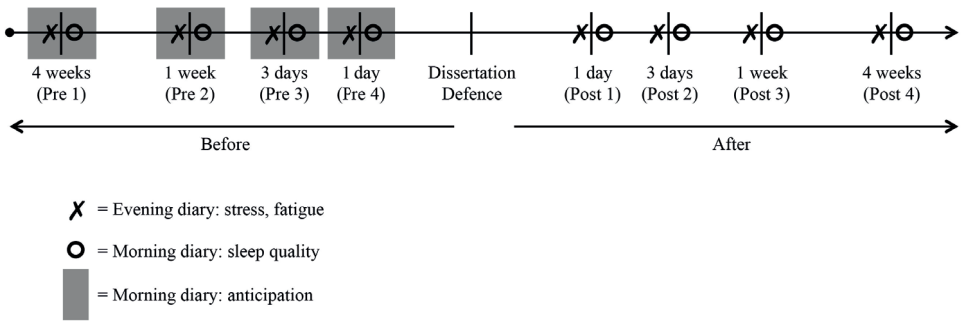

Figure 5.1 Visualization of measurement occasions and design

5.2.2 Participants

Every month between July 2013 and March 2015, all PhD students affiliated to a university in the eastern part of the Netherlands, and those awaiting their dissertation defence within 2 months, were invited to participate in the study (approximately 10-40 PhD students per month). In total, 356 PhD students were contacted via e-mail. A substantial part of the PhD students, however, was not eligible for participation because they did not live nearby the university. This was a requirement as all participants were asked to wear actigraphs during all measurement occasions and, therefore, had to meet with the first author for a demonstration on how to use the device correctly (objective sleep data are reported elsewhere). The exact number of non-eligible participants was not known as, for anonymity reasons, the Executive Board of the university only provided us with the PhD students' e-mail addresses. Forty-eight PhD students agreed and were eligible to take part in the study, of which 44 respondents finished the study. The majority of the sample was female (79.5%) and the mean age was 35.0 years (*SD* = 10.1 years). Participants were from the Faculty of Medical Sciences (36.4%), Faculty of Social Sciences (13.6%), Faculty of Arts (11.4%), and Faculty of Science (consisting of Natural Sciences, Mathematics and Computer Science; 11.4%). The dissertation defence is usually several months after the PhD contract has ended, and consequently, about two thirds of participants (68.2%) had a (new) job.

5.2.3 Diary measures

Momentary stress was assessed using two items adapted from the daily well-being measurement used by Radstaak, Geurts, Beckers, Brosschot, and Kompier (2014a). Respondents rated their momentary feelings of stress. The items were "How stressed do you currently feel?" and "How relaxed do you currently feel?" (reversed). Both items were rated on a 10-point (1 = not at all, to 10 = very much) scale, consistent with the Dutch grading system. A higher score indicated higher level of stress.

Three items were used to assess *momentary fatigue,* of which two items were adapted from the daily well-being measurement used by Radstaak et al. (2014a). A third item was constructed to represent whether participants felt well rested and the wording was identical to the other two items. The items were "How tired do you currently feel?", "How energized do you currently feel?" (reversed), and "How well-rested do you currently feel?" (reversed). A 10-point scale was used to rate all items (1 = not at all, to 10 = very much), with a higher score indicating a higher level of fatigue. Reliability coefficients for the fatigue scale were mostly good to excellent (*M* Cronbach's α coefficients across all measurement occasions: 0.80; range: 0.60 - 0.91).

To measure *day-level subjective sleep quality*, the Sleep Quality Index (Kecklund & Åkerstedt, 1997) was used. This index consists of four items, all rated on a 5-point scale (1 = not at all, to 5 = very much). Higher scores indicated higher sleep quality, and the reliability coefficients of all but three measurement points were acceptable or good (*M* Cronbach's α coefficients across all measurement occasions: 0.68; range: 0.55 - 0.84). An example item was "Did you have trouble falling asleep last night?".

Positive anticipation was assessed with one item, asking participants whether they were looking forward to their defence. *Negative anticipation* was measured with the item "I am already nervous for my defence". *Positive outcome expectancy* was assessed by asking participants whether they believed that their defence would go well. All items were rated on a 5-point scale (1 = strongly disagree, to 5 = strongly agree), with higher scores indicating high positive anticipation, high negative anticipation, and more positive outcome expectancy.

5.2.4 Statistical approach

Average scores for momentary stress, momentary fatigue, and day-level sleep quality were computed. Three repeated measures multivariate analyses of variance (RM-MANOVA) were used to analyse the development of stress, fatigue, and sleep quality leading up to and following the defence. The repeated measures factor was measurement occasion and the outcome variables were stress, fatigue, and sleep quality. First, the four pre-measurements of stress, fatigue, and sleep quality were examined (*Pre 1-4*). In the second analysis, measurements of stress, fatigue, and sleep quality directly before and after the defence were compared (*Pre 4/Post 1*). The third analysis concerned a comparison of the post-defence measurements (*Post 1-4*) for stress, fatigue, and sleep quality. Missing data during post-measurements were higher than during pre-measurements. To handle missing data, Post 2 and Post 3 were combined and the average score of the two measurements was used in the analysis. In another RM-MANOVA, the time course of the three anticipation items was examined. Linear and quadratic time trends of all significant effects were inspected. The most significant trend was reported.

Finally, we performed multilevel analysis in SPSS (Hox, 2010; Snijders & Bosker, 1999) to investigate whether day-level positive anticipation, negative anticipation, and positive outcome expectancy predicted day-level scores on stress, fatigue, and sleep quality. Multilevel analysis accounts for the fact that our data at the day level (level 1) were nested within persons (level 2). Because we were exclusively interested in within-person changes, all independent variables (i.e., positive anticipation, negative anticipation, and positive outcome expectancy) were centered around their respective person-mean (Hofmann, Griffin, & Gavin, 2000). The out-

come variables stress, fatigue, and sleep quality were not centered. In multilevel analysis, several models can be tested and compared to each other. To examine daily relations between positive anticipation, negative anticipation, and positive outcome expectancy on the one hand, and stress, fatigue, and sleep quality on the other hand, three models were analysed for each of the outcome variables. In the null model, only the intercept was entered. In subsequent models, predictors were entered. Because some of the day-level outcome variables were correlated with each other, model 1 included the two other outcome variables as control variables (e.g., in the analyses where day-level stress was the outcome variable, day-level fatigue and sleep quality were included as control variables). Finally, model 2 included the three day-level predictors positive anticipation, negative anticipation, and positive outcome expectancy. Whether the final model fitted the data better than a previous model was assessed by computing the differences of the respective log-likelihood statistic (–2*log) and submitting this difference to a chi squared (χ^2) test. A significant χ^2 difference indicated that the final model had better fit with the data than previous models.

5.3 RESULTS

5.3.1 Descriptive statistics and correlations

Person-level (between participants) as well as day-level (within participants) correlations are presented in Table 5.1. Almost all correlations were in the expected direction, but not all hypothesized correlations were significant.

Table 5.1 Correlations of variables under study

	1	2	3	4	5	6
1. Stress		.26	-.32*	-.11	.64**	-.24
2. Fatigue	.24**		-.27	-.29	.24	-.32*
3. Sleep quality	-.13	.01		.08	-.25	.16
4. Positive anticipation	-.06	-.17*	.04		-.24	.74**
5. Negative anticipation	.51**	.07	-.13*	-.17*		-.12
6. Positive outcome expectancy	-.19*	-.15	.21**	.65**	-.10	

Note: Above diagonal person-level (n = 44), below diagonal day-level (n = 174)
* $p < .05$, ** $p < .01$

5.3.2 Time course of stress, fatigue, and sleep quality

See Figure 5.2 for a visual representation of the time course of stress, fatigue, and sleep quality. In Table 5.2, the results of all MANOVA analyses regarding stress, fatigue, sleep quality, and anticipation are presented. Participants reported a significant increase in *stress* level leading up to the defence and this increase followed a linear trend ($p < .001$, $\eta_p^2 = .21$). Comparing stress directly before the defence to directly after defence, stress level decreased significantly, and in absolute levels the Post 1-4 measurements were lower than the Pre 1 measurement of stress. No significant change in stress during the four weeks after defence was observed. These results largely support hypothesis 1.

Results did not indicate a significant change in *fatigue* leading up to the defence. We did find a significant increase in fatigue from directly before to directly after the defence. Fatigue level of participants decreased during the period following the defence. This pattern followed a linear trend ($p < .05$, $\eta_p^2 = .15$). Consequently, hypothesis 2 was confirmed.

No change in *sleep quality* leading up to defence was detected. Results did indicate a significant increase in sleep quality from directly before to directly after the defence. During the four weeks following defence, no change in sleep quality was observed, only partially supporting hypothesis 3.

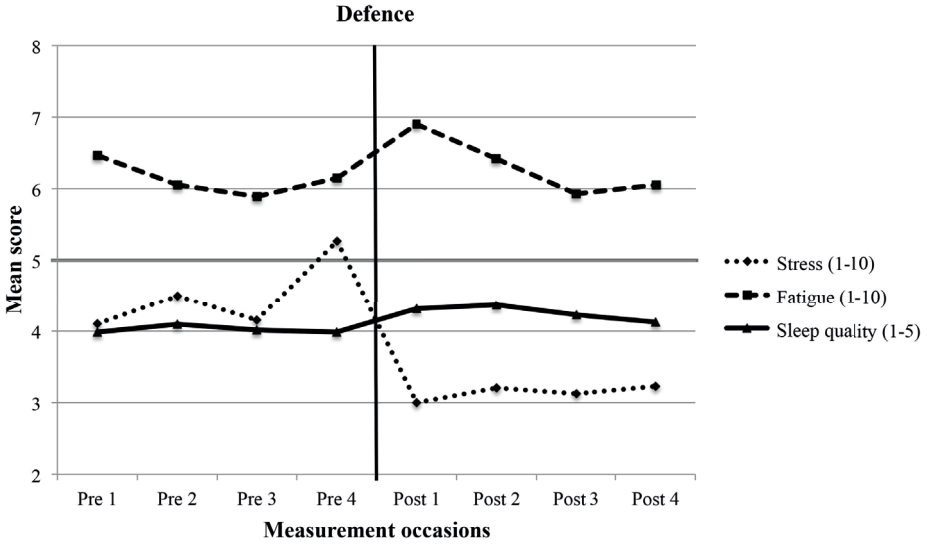

Figure 5.2 Line diagram of means for stress, fatigue, and sleep quality across all eight time points
Note: Range SD_{stress} = *1.25 - 2.03;* range $SD_{fatigue}$ = *1.44 - 1.90;* range $SD_{sleep\ quality}$ = *0.58 - 0.87*

Table 5.2 Results of MANOVA analyses concerning the time course of stress, fatigue, and sleep quality as well as the development of anticipation leading up to the defence

	Leading up to defence				Comparing days directly before and after defence				Following defence				Exploratory baseline check			
	F (df)	*p*	η_p^2	↑/↓/--	*F (df)*	*p*	η_p^2	↑/↓/--	*F (df)*	*p*	η_p^2	↑/↓/--	*F (df)*	*p*	η_p^2	↑/↓/--
Stress, fatigue, and sleep quality																
Stress	7.43 (3, 123)	< .001	.15	↑	55.31 (1, 40)	< .001	.58	↓	0.79 (2, 78)	.46	.02	--	13.03 (1, 40)	< .001	.25	↓
Fatigue	1.54 (3, 123)	.21	.04	--	7.59 (1, 40)	< .05	.15	↑	6.07 (2, 78)	< .01	.14	↓	1.38 (1, 40)	.25	.03	--
Sleep quality	0.14 (3, 123)	.94	.00	--	6.25 (1, 40)	< .05	.14	↑	1.22 (2, 78)	.30	.03	--	2.12 (1, 40)	.15	.05	--
Anticipation																
Positive anticipation	2.69 (3, 126)	< .05	.06	↑												
Negative anticipation	18.06 (3, 126)	< .001	.30	↑												
Positive outcome expectancy	0.73 (3, 126)	.54	.02	--												

Note: ↑ increase, ↓ = decrease, -- = no change

To check whether the first measurement point four weeks before defence was a good baseline measure, an exploratory RM-MANOVA analysis was performed. Stress, fatigue, and sleep quality on the first and last measurement occasion were compared to each other (*Pre 1/ Post 4*). The analysis showed that stress was significantly higher four weeks before the defence than four weeks after the defence, indicating that stress levels were already elevated at the first measurement point. No differences in fatigue or sleep quality were detected between Pre 1 and Post 4.

5.3.3 Anticipation leading up to defence

A visual representation of anticipation leading up to the defence is presented in Figure 5.3. Analysis revealed that *positive anticipation* increased significantly leading up to the defence and followed a quadratic trend ($p < .05$, $\eta_p^2 = .13$), meaning that positive anticipation first slightly decreased, and then increased again. At the same time, *negative anticipation* increased steeply with the defence approaching. This pattern followed a linear trend ($p < .001$, $\eta_p^2 = .49$). Regarding *positive outcome expectancy*, no changes over time were detected. Consequently, hypothesis 4 was partially supported.

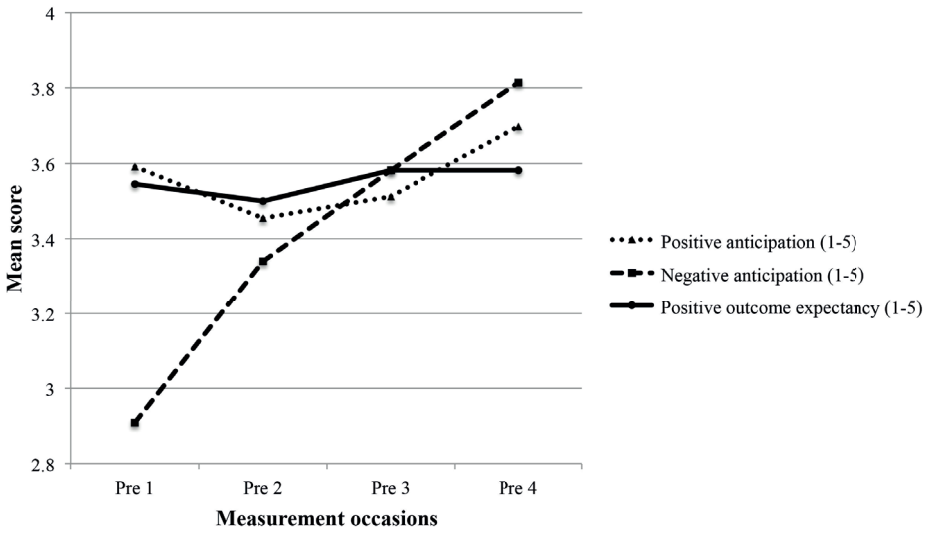

Figure 5.3 Line diagram of means for positive anticipation, negative anticipation, and positive outcome expectancy across pre measurements
Note: Range $SD_{positive\ anticipation}$ = *0.80 - 0,95;* range $SD_{negative\ anticipation}$ = *0.93 - 1.08;* range $SD_{positive\ outcome\ expectancy}$ = *0.63 - 0.73*

5.3.4 Day-level relations between anticipation and stress, fatigue, and sleep quality

Intra-class correlations showed that 52% of the variance in stress was at the day level (within-person). Thus, half of the variance in stress can be attributed to daily fluctuations. Moreover, 17% of variance in fatigue and 12% of variance in sleep quality were at the person level, indicating that most of the variance of fatigue and sleep quality was at the day level (within-person day-level fluctuations). This makes our hypotheses on day-level relations between anticipation measures and outcomes relevant.

All tested models are presented in Table 5.3. Regarding day-level *stress*, model 1 provided a better fit than the null model, as higher day-level fatigue was predictive of subsequent stress. However, model 2 fitted the data significantly better than model 1. This model showed that high daily scores on negative anticipation (nervousness) and low daily scores on positive outcome expectancy were related to higher daily stress. Daily positive anticipation was not related to day-level stress. Thus, hypothesis 5a was partially supported.

Results with day-level *fatigue* as outcome variable showed that model 1 fitted the data significantly better than the null model, showing that higher day-level stress was predictive of subsequent fatigue. Model 2 did not improve model fit. Daily positive anticipation, negative anticipation, and positive outcome expectancy were not related to daily fatigue, not lending support to hypothesis 5b.

Concerning day-level *sleep quality*, model 1 did not provide a better fit than the null model. Model 2, however, provided a significantly better fit than the null model and model 1. Neither day-level positive nor negative anticipation was related to daily sleep quality. However, higher day-level scores on positive outcome expectancy were related to better sleep quality on a daily basis, partially supporting hypothesis 5c.

One important note here is that even though positive anticipation and positive outcome expectancy are conceptually different, they were highly correlated in this study. We therefore conducted post hoc analyses to examine whether multi-collinearity may have affected the findings for positive anticipation. In the first post hoc analysis, we included positive anticipation and negative anticipation (positive outcome expectancy excluded) to predict day-level stress, fatigue, and sleep quality. In the second analysis, daily negative anticipation and positive outcome expectancy were included (positive anticipation excluded). Results of these analyses were identical to the initial analyses including all three concepts simultaneously; multi-collinearity did not account for the absence of significant findings on positive anticipation. Findings of the post hoc analyses can be requested from the first author.

Table 5.3 Daily relations of positive anticipation, negative anticipation, and positive outcome expectancy with stress, fatigue, and sleep quality

	Stress			Fatigue			Sleep quality		
	Null model estimate	Model 1 estimate	Model 2 estimate	Null model estimate	Model 1 estimate	Model 2 estimate	Null model estimate	Model 1 estimate	Model 2 estimate
Intercept	4.50**	3.50**	2.70**	6.14**	4.41**	4.54**	4.02**	4.03**	4.03**
Stress					.23*	.27**		-.05	-.03
Fatigue		.24*	.29**					.04	.02
Sleep quality		-.13	.01		.18	.10			
Positive anticipation			.19			-.26			-.17
Negative anticipation			.58**			-.33			.01
Positive outcome expectancy			-.82*			.64			.75**
-2* log	657.34	646.50	626.84	641.50	630.03	623.31	388.35	385.71	369.46
Diff -2* log		10.84**	19.66**		11.47**	6.72		2.64	16.25**
ΔDf		2	3		2	3		2	3
Level 1 intercept var.	1.77	1.67	1.43	2.05	1.89	1.80	.50	.49	.43
Level 2 intercept var.	1.64	1.51	1.61	.43	.44	.46	.07	.06	.08
R^2 (within persons)	.00	.06	.18	.00	.08	.12	.00	.02	.14
R^2 (between persons)	.00	.08	.02	.00	.02	.07	.00	.14	.14

Note: * $p < .05$, ** $p < .01$

5.4 DISCUSSION

The main aim of the present study was to examine how stress, fatigue, and sleep quality unfold leading up to and following a work-related stressful event (i.e., the dissertation defence). Key findings were that stress increased leading up to the defence and decreased rapidly following the defence. Fatigue did not increase leading up to the defence but increased immediately following the defence and slowly decreased thereafter. Sleep quality did not deteriorate leading up to the defence but did improve directly following the defence. During the four weeks after the defence, no additional changes in sleep quality were detected. The second goal of this study was to clarify whether cognitive anticipation of the stressful event influences stress, fatigue, and sleep quality on the day level. Positive and negative anticipation increased before the defence, whereas positive outcome expectancy remained rather stable. Day-level stress was adversely affected by day-level negative anticipation and favourably by positive outcome expectancy, whereas positive anticipation had no influence. Day-level fatigue was not influenced by any of the anticipation indicators. Only positive outcome expectancy was an important predictor of improved sleep quality on the day level.

5.4.1 Stress, fatigue, and sleep quality leading up to defence

Results showed an increase in stress leading up to the defence, while sleep quality remained stable and high. Fatigue was stable and moderate before the defence. Even though stress increased over time, absolute stress levels remained moderate. The physiological arousal accompanying these moderate stress levels may not have been high enough to affect sleep quality. Thus, participants may have been able to recover from day-level stress during satisfactory sleep, offering an explanation for the stable fatigue levels. These findings are mostly in line with the Effort-Recovery theory and other research on stress and recovery, in which it is argued that effects of stress on recovery-related health indicators are only unfavourable when individuals do not recover adequately from stress on a day-to-day basis (such as when they do not sleep well; Geurts & Sonnentag, 2006; McEwen, 1998; Meijman & Mulder, 1998). Moreover, we assume that motivation to perform well on the day of the defence was high, which may have suppressed feelings of fatigue (Hockey, 2013).

5.4.2 Stress, fatigue, and sleep quality directly before and after defence

Comparing the night before the defence with the night after, stress and sleep quality followed the expected pattern. In line with Effort-Recovery theory and previous

research, stress rapidly decreased, whereas fatigue and sleep quality increased (Åkerstedt et al., 2009; Brosschot et al., 2006; Hockey, 2013; Meijman & Mulder, 1998; Oosterholt et al., 2014). It seems plausible that living toward a planned stressful event evokes heightened stress long before the event itself takes place (potentially even before our baseline measurement) but as soon as the stressful event has passed, stress quickly declines and sleep quality improves. Participants were tired the day after the defence but were simultaneously relaxed and slept well during the subsequent night. The increase in fatigue may be explained with the help of motivation. As alluded to above, we assume that motivation to perform well is high. Hence, motivation may overrule feelings of fatigue leading up to the defence (Hockey, 2013; Hopstaken et al., 2015; Oosterholt et al., 2014). Once the defence is over and the urge to perform well has gone, motivation declines, and fatigue may manifest itself. Consequently, PhD students are 'paying the price' for suppressed fatigue leading up to the defence, a process in which high motivation possibly increases adrenaline, which in turn overrules feelings of fatigue. An additional explanation for the rapid increase in fatigue right after the defence may be related to celebratory activities taking place on the day of the dissertation defence and the subsequent night. The celebrations may have resulted in tiredness on the day after the defence, on which fatigue level was measured.

5.4.3 Stress, fatigue, and sleep quality following defence

During the four weeks following the defence, no changes in stress or sleep quality were detected, but we did observe a decline in fatigue levels. The decline in fatigue was expected; we assume that after long-term suppression of fatigue leading up to the defence and the steep increase thereafter (the 'price' PhD students had to pay), fatigue levels return to normal. Our finding that stress remained stable low and sleep quality stable high during post-measurements was not in line with our expectations. Rather than slowly returning to baseline levels, stress and sleep quality seem to have returned to normal levels directly after the stressful event had passed.

5.4.4 Anticipation leading up to defence

Regarding anticipation and in line with our expectations, negative anticipation (nervousness) increased leading up to the defence (Åkerstedt et al., 2004; Kecklund & Åkerstedt, 2004). Contrary to our expectations, positive anticipation (looking forward) also increased as the defence approached, and positive outcome expectancy remained stable and was generally high. PhD students became more nervous as the date of the defence neared but at the same time remained relatively optimistic: they increasingly looked forward to the defence and had

positive outcome expectancies. These findings seem to indicate that positive and negative anticipation is not two extremes of one continuum but can coexist.

5.4.5 The role of anticipation on the day level

Finally, our study showed that day-level measures of anticipation were related to day-level measures of stress and sleep quality. Based on our findings, we tentatively conclude that not so much the positive anticipation of (i.e., looking forward to) a stressful situation may have implications for daily stress and sleep quality, but rather the belief that one will perform well (i.e. positive outcome expectancy) and the level of day-level nervousness one feels (i.e., negative anticipation). These findings extend the prolonged activation model (Brosschot et al., 2005) and previous research by showing that positive outcome expectancy plays a crucial role in predicting stress and sleep quality on the day level. Day-level relations are important because stress and sleep quality have been shown to vary from day to day (Mezick et al., 2009). Day-level fatigue was not associated with any of the anticipation indicators. Because we argue that feelings of fatigue may have been suppressed by motivational processes, this may also explain that anticipatory cognitions were not related to fatigue. The finding that positive anticipation (looking forward) was not associated with any of the day-level outcomes, was not in line with our expectations and with previous research (Ong et al., 2006; Papousek et al., 2010; Tugade & Fredrickson, 2004).

5.4.6 Limitations and suggestions for future research

The present study has some limitations. Firstly, it is reasonable to assume that our study included a selective sample, with only the more relaxed PhD students agreeing to participate. This is reflected in their overall favourable scores on stress, fatigue, sleep quality, and anticipation. Additionally, most non-participating PhD-students mentioned negative anticipation, high feelings of stress, and inability to cope with stress as their main reasons not to participate. The non-representative sample has consequences for the generalizability of results. Our findings on the prevalence, time course and day-level covariation of anticipation, stress, fatigue, and sleep quality may only be representative for individuals who are able to cope well with stressful situations. It is important to note that our findings may well be an underestimation of the actual effects (cf. restriction of range and healthy worker effect). In a representative sample, the time course of stress, fatigue, and sleep quality would likely be more pronounced and its day-level relation with anticipation stronger. Future research should take this into consideration and try to include a more heterogeneous sample in terms of stress coping skills and anticipatory feelings.

Another limitation is that measures of stress and fatigue included a limited number of items each, which may impact validity. However, in multi-wave diary research, it is not feasible to use many items to assess concepts, as missing data and dropouts increase when diaries are time-consuming. Additionally, previous research has shown that single-item measures can be a valid alternative to multiple-item measures. For example, Van Hooff, Geurts, Kompier, and Taris (2007) showed that a single item measuring daily fatigue was psychometrically equivalent to multiple-item measures of fatigue (i.e., Profile of Mood States). Similarly, Elo et al. (2003) demonstrated that a single-item measure of stress was as valid as multiple-item measures of stress (i.e., Maslach Burnout Inventory, General Health Questionnaire). A related issue, however, is that fatigue was used as a proxy for insufficient recovery. Although fatigue is a frequently used and accepted measure of incomplete recovery (Sonnentag & Geurts, 2009), more complete measures of stress and recovery state may be used in future research.

A final limitation concerns timing of measurements. We decided not to bother participants on the day of the defence to limit stress due to participation in the study and to minimize dropout. Nevertheless, information gathered on the day of defence would have given us more detailed insights into stress, fatigue, and sleep quality related to the defence. Future studies may benefit from using non-intervening devices to monitor, for instance, heart rate of participants. Another suggestion would be to assess performance during the defence (e.g., by means of self-assessment, assessment by supervisor, and assessment by researchers). But future research should take into account the trade-off between gathering information and participant dropout. Moreover, our results indicate that four weeks before the defence was not a suitable baseline measurement as stress was already much higher four weeks before the defence compared to several weeks after the defence. Future research on the time-course of stress related to a foreseeable stressful event may start monitoring workers earlier.

As personality-related factors such as day-level anticipation and positive outcome expectancy were related with day-level stress and sleep quality, it may be valuable to help employees who face foreseeable stressful periods at work, to cope with (future) stressful events effectively. Of course, where possible, employers should limit work-related sources of stress, for example, by preventing excessive job demands and promoting employee job control. In case of unavoidable stress, organizations should additionally teach their employees stress management and coping strategies such as time management or relaxation techniques to deal with unavoidable stress (Gu, Strauss, Bond, & Cavanagh, 2015; Häfner, Stock, Pinneker, & Ströhle, 2014; Richardson & Rothstein, 2008). Time management strategies, for example, have been shown to increase control, which reduces anxiety and is

beneficial for self-confidence (Claessens, Van Eerde, Rutte, & Roe, 2007). Reduced anxiety and increased self-confidence, in turn, may promote positive outcome expectancies and diminish negative anticipation of stressful events, which may lower day-level stress and improve day-level sleep quality. Additionally, research has shown that stress is closely related to long-term sickness absence and turnover (Duraisingam, Pidd, & Roche, 2009; Grynderup et al., 2016). Because the present study showed that stress is already elevated long before a stressful event takes place, long-term employee absence and turnover may become more likely in anticipation of or during these stressful periods and, thus, should be avoided by teaching employees how to handle stress and stressful situations, and giving employees enough opportunities for recovery.

Overall, our findings support previous research on stress, fatigue, and sleep quality and add that day-level anticipation may play an important role in day-level stress and sleep quality in anticipation of a stressful work-related event.

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Chapter 6

Day-to-day relations between stress and sleep and the mediating role of perseverative cognition

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ABSTRACT

The goals of this longitudinal diary-based study were to shed light on the day-level relationship between stress and subsequent sleep, and to examine whether perseverative cognition is a mediating factor in this relation. A total of 44 Dutch PhD students were followed during a two-month period, from one month before their public thesis defence (i.e., a stressful life event), until one month thereafter. Participants completed short evening and morning questionnaires on eight occasions (in anticipation of and following the defence) including questions about day-level stress, sleep quality, and perseverative cognition. Objective sleep parameters were collected with the SenseWear Pro Armband. Multilevel analysis was used to analyse daily observations nested within individuals. Analyses revealed that day-level stress was not directly related to subsequent subjective sleep indicators or to subsequent objective sleep indicators. Day-level stress was significantly associated with day-level perseverative cognition, and daily variations in perseverative cognition were significantly related to several day-level objective sleep parameters (sleep efficiency, marginally to number of awakenings, and wake after sleep onset), and to several day-level subjective sleep parameters (sleep quality, number of awakenings, wake after sleep onset). Finally, mediation analyses using path analysis suggested that, on the day level, perseverative cognition functions as a mediator between stress and several sleep parameters, namely, subjective sleep quality, objective sleep efficiency, and subjective wake after sleep onset. Perseverative cognition is a promising explanatory mechanism linking day-level stress to subjective and objective measures of sleep.

6.1 INTRODUCTION

It has been reported that one-third of people suffer from poor sleep and roughly 10% meet the criteria for insomnia (LeBlanc et al., 2009; Ohayon & Reynolds, 2009). Sleep quality (the experience of sleep in terms of sleep continuity) and sleep quantity (duration of sleep) are both important aspects of sleep (Åkerstedt et al., 1994a; Åkerstedt et al., 2009). Low sleep quality is characterized by difficulties initiating sleep (long sleep onset latency) and difficulties maintaining sleep (high number of awakenings, long duration of awakenings).

Sleep quality and sleep quantity can be assessed objectively, but subjective measures of sleep indicators have also been widely used to assess sleep (Landry et al., 2015). Subjective and objective measures of sleep do not always concur (Landry et al., 2015; Unruh et al., 2008) and it has been suggested that this is due to the fact that both methods measure different underlying processes. However, both provide valuable insights into sleep patterns (Harvey et al., 2008; Landry et al., 2015; Tworoger et al., 2005). By assessing both objective and subjective sleep parameters a complete overview of sleep is achieved, which improves the validity of results (Van Laethem et al., 2015).

Previous research has shown that subjective as well as objective indicators of poor sleep are related to poor health (Barone & Menna-Barreto, 2011; Cappuccio et al., 2010; Maglione et al., 2014; Taylor et al., 2005; Vgontzas et al., 2009; Wolk et al., 2005). As such, it is important to know the causes of poor objective and subjective sleep (Åkerstedt, 2006). Several reviews have provided evidence for a cross-sectional and longitudinal relationship between (work-related) stress and objective and subjective sleep parameters. A review of all cross-sectional studies, for example, found that stress is related to shortened sleep and sleep fragmentation (Åkerstedt, 2006). Moreover, a recent review of longitudinal and intervention research has shown that job demands are negatively related and job control is positively related to sleep quality (Van Laethem et al., 2013).

It has been suggested that perseverative cognition (PC) (Brosschot, 2010; Brosschot et al., 2006) is a key mediator in the relationship between stress and poor sleep. PC is defined as "repeated or chronic activation of the cognitive representation of one or more psychological stressors" (Brosschot et al., 2006, p.114) and is related to both stress and sleep complaints (Brosschot, 2010; Van Laethem et al., 2015). It appears that perseverative cognitions about stressors or stressful situations prolong physiological activation that occurs in response to stressors and hinder sleep itself and physiological restoration (recovery) during sleep (Åkerstedt et al., 2009).

Longitudinal studies (with time lags of one year or longer) suggest that PC may mediate the relationship between stress and sleep (Åkerstedt et al., 2012; Van Laethem et al., 2015). However, longitudinal research has focused mostly on between-person differences in PC, and only in a few studies have within-person fluctuations been considered (Brosschot, Van Dijk, & Thayer, 2007). As such, these longitudinal studies with long time lags do not take into account that stress, sleep, and PC show day-level fluctuations within an individual and may co-vary accordingly (Mezick et al., 2009).

We set out to investigate whether within-person variations in stress are related to within-person fluctuations in objective and subjective sleep. Second, this study examined whether day-level PC functions as a mediator in this relationship. To provide an answer to these research questions and to ensure a high-stress sample with high within-person variation in stress, PC, and sleep, we chose to study PhD students awaiting and following their PhD dissertation defence. The PhD dissertation defence, which is public in the Netherlands, has previously been described as a strong and well-defined real-life stressor (Van Doornen & Van Blokland, 1992) and consequently we expect naturally occurring, daily fluctuations in stress. We predict that daily stress is adversely associated with subsequent day-level objective sleep parameters (Hypothesis 1) and with day-level subjective sleep parameters (Hypothesis 2). Moreover, we hypothesized that day-level PC mediates day-to-day relationships between stress on the one hand and objective sleep parameters (Hypothesis 3) and subjective sleep parameters (Hypothesis 4) on the other.

6.2 METHODS

6.2.1 Procedure and design

In this study, we followed a group of PhD students before and after a predictable, stressful event: the PhD dissertation defence. In the Netherlands, the dissertation defence is a one-hour public oral examination in front of an audience and several expert professors who act as opponents. During the first ten minutes of the dissertation defence, the PhD student gives a presentation introducing his or her PhD thesis. In the remaining 50 minutes, he or she has to answer critical questions, both unknown and usually unexpected, from the professors. The dissertation defence is a situation of low control and has a high social evaluative component, demanding peak performance. Therefore, the defence is commonly experienced as being fairly stressful (Van Doornen & Van Blokland, 1992).

For each participant, data collection for this study took place during a time span of eight weeks, starting four weeks before the dissertation defence and ending four weeks after. Four measurements occurred before the dissertation defence [four weeks (Pre 1), one week (Pre 2), three days (Pre 3), one day (Pre 4) before the dissertation defence] and four measurements were done after the dissertation defence [one day (Post 1), three days (Post 2), one week (Post 3), and four weeks (Post 4)]. Before taking part in the study, participants were given detailed information about the research procedure and provided informed consent.

At Pre 1, respondents were asked to fill in a general questionnaire regarding demographic information, psychosocial work characteristics (i.e., average job demands and job control), general stress and overall sleep quality. On all eight day-level measurement occasions, respondents received a short digital questionnaire via e-mail at 7 p.m. and another questionnaire the following morning (7 a.m.). Participants were asked to fill in the evening questionnaire at bedtime and the morning questionnaire shortly after awaking. In the evening questionnaire, momentary feelings of stress were measured. In the morning questionnaire, parameters of subjective sleep of the previous night were assessed as well as bedtime PC. Bedtime PC was measured in the morning to avoid interference with subsequent sleep. During the night in between both diaries (discussed later here), objective sleep was measured with an actigraph. Respondents could choose to receive reminders for completing the diaries in the form of text messages. Text messages were sent as requested by respondents: in the evening, morning or on both occasions. Figure 6.1 provides a visualization of the design and an overview of measurement occasions.

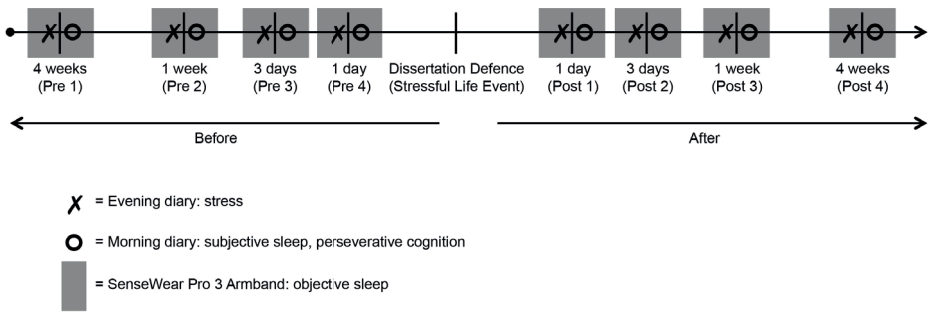

Figure 6.1 Visualization of study design and overview of measurement occasions

Two lottery prizes were raffled among respondents to promote participation and reduce missing data. Winners could choose between an iPad mini and a holiday park gift card matching the value of the iPad mini (i.e., €389). Respondents who filled in all diaries had a higher chance of winning than respondents with missing data. The present study was approved by the Ethics Committee of the Faculty of Social Sciences of the university involved, and written informed consent was obtained from all participants.

6.2.2 Participants

Once a month between July 2013 and March 2015, all PhD students affiliated with a university in the Netherlands and awaiting their dissertation defence within two months were invited to participate (i.e., 10-40 PhD students each month). In total, 356 PhD students were contacted via e-mail. However, many of these were not eligible to participate in the study. For instance, several PhD students did not understand the Dutch language and therefore could not understand the study materials. Moreover, many potential participants did not live near the university, which was necessary for distributing the actigraphs. In addition, only few participants could be tested simultaneously as availability of actigraphs was limited. To ensure anonymity, the Executive Board of the university provided us with only the PhD students' e-mail addresses, and no other information to distinguish, for instance, foreign PhD students. As not all eligible and all not-eligible PhD students responded to our invitation, the exact number of eligible persons was unknown, and a response rate cannot be calculated. A total of 48 PhD students agreed to participate, of whom 44 respondents finished the study (i.e., filled in most questionnaires). All respondents filled in the general questionnaire. Missing data were low for the evening and morning questionnaires. For both the morning and evening questionnaire, twelve questionnaires (3%) of 352 possible data points (44 respondents x 8 measurement occasions) were missing. Missing data of the actigraph data were somewhat higher, with 39 nights missing among 352 (11%). The sample was predominantly female (79.5%) and the mean age was 35.0 years [standard deviation(*SD)* = 10.1 years]. Several faculties of the university were represented, with most participants from the Faculty of Medical Sciences (36.4%), Faculty of Social Sciences (13.6%), Faculty of Arts (11.4%), and Faculty of Natural Sciences, Mathematics and Computer Science (11.4%).

6.2.3 Measures

Objective sleep measures (actigraphy)

Although polysomnography is regarded as the gold standard in sleep research (Jackowska, Dockray, Hendrickx, & Steptoe, 2011; Landry et al., 2015; Michaelson, Allan, Chaney, & Mair, 2006), recent field research has used actigraphy. Actigraphs have been positively validated against polysomnography (Ancoli-Israel et al., 2003; Morgenthaler et al., 2007; Sharif & Bahammam, 2013). In this study, the SenseWear Pro 3 Armband (BodyMedia, Inc., Pittsburgh, PA, USA) was used to assess objective sleep parameters by means of actigraphy. This armband is a validated measurement instrument and has been shown to correspond well with polysomnography in healthy populations as well as in patients with obstructive sleep apnea (Sharif & Bahammam, 2013). The SenseWear armband is a multisensory body monitor and contains a two-axis accelerometer, a heat flux sensor, a galvanic skin response sensor, skin, and near-body temperature sensors. The armband was worn above the triceps muscle on the left arm during all measurement occasions (from shortly before bedtime until arising in the morning). For each participant, and on each measurement occasion, data from all sensors were combined and were analysed with algorithms developed by the SenseWear company (SenseWear professional software, version 7.0). Algorithms were used to estimate sleep parameters in epochs of one minute. The algorithm for extracting sleep parameters returned binary data for 'lying down' (0 = no, 1 = yes) and 'sleeping' (0 = no, 1 = yes). Recommendations for standard assessment in sleep research were used to determine total sleep time, sleep onset latency, number of awakenings, and wake time after sleep onset (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006).

Sleep efficiency (SE) was derived by dividing the total sleep time by the total time in bed and was expressed as a percentage. *Total sleep time* (objective TST) was measured in minutes and represented the total sum of the minutes scored sleeping from sleep onset until the final awakening. *Sleep onset latency* (objective SOL) was assessed as the minutes in-between lying down and the start of sleep onset. The *number of awakenings* (objective NWAK) was the number of periods during which the participant was awake, excluding the final awaking. *Wake after sleep onset* (objective WASO) was the total time awake during the night between sleep onset and final awakening and was measured in minutes.

Subjective sleep measures

Sleep quality (SQ) of the previous night was assessed with one item from the validated Karolinska Sleep Diary (KSD) (Åkerstedt et al., 1994a; Åkerstedt, Hume, Minors, & Waterhouse, 1994b). This item was worded "How well did you sleep?" and

was rated on a 5-point scale (1 = very poor, 2 = rather poor, 3 = not poor, nor good, 4 = rather good, 5 = very good). *Total sleep time* (subjective TST) in minutes was derived by subtracting self-reported bedtime and self-reported sleep onset latency from self-reported final awakening time. Bedtime was measured with the item "At what time did you go to sleep last night?", and awakening time was assessed with the item "At what time did you awake this morning?". *Sleep onset latency* (subjective SOL) in minutes was measured with the item "How long did it take last night until you fell asleep?". *Number of awakenings* (subjective NWAK) was assessed with an item of the KSD and was worded "How often did you wake up during the night?". Response categories were: 1 = not at all, 2 = once, 3= twice, 4 = 3 times, 5 = 4 times, 6 = 5 times, 7 = > 5 times. *Wake after sleep onset* (subjective WASO) was also measured with an item from the KSD: "How long have you (approximately) been awake during the sleep period?". The item was rated on a 5-point scale (1 = not at all, 2 = a few minutes, 3 = 10-30 minutes, 4 = 3/4-1 hour, 5 = > 1 hour).

Day-level stress and PC

Momentary stress was measured in the evening and assessed by calculating the mean score of two items adapted from the daily well-being measurement used by Radstaak, Geurts, Beckers, Brosschot, and Kompier (2014a). Respondents rated their momentary feelings of stress using the following items: "How stressed do you currently feel?" and "How relaxed do you currently feel?" (reversed). Following the Dutch grading system, the two stress items were rated on a 10-point scale (1 = not at all, to 10 = very much). A higher mean score indicated a higher level of stress.

Day-level perseverative cognition was assessed in the morning to prevent interference with subsequent sleep. A multi-response item was used to assess the content of perseverative cognitions. The item was worded "Did you have perseverative cognitions at bedtime or during the night? Multiple answers are possible." Possible response categories were "yes, about work; yes, about my dissertation defence; yes, about job insecurity; yes, about private matters; yes, about my sleep patterns; yes, about other things". In the case of no PC, respondents did not mark any of the answer boxes. Responses were added (every ticked box = 1 point) with a higher score indicating multiple perseverative cognitions. We assume that multiple perseverative cognitions indicate more intense PC. It should be noted that PC was not specifically defined for participants as the Dutch equivalent of PC (i.e., 'piekeren') is a well-known and frequently used term in everyday life.

6.2.4 Statistical analyses

We performed multilevel path analysis with ML estimation using Mplus 7 (Muthén & Muthén, 1998-2012) to examine day-to-day relations between stress and sleep.

Moreover, we carried out multilevel mediation analyses to investigate whether day-level PC mediated this relationship. Associations between constructs can be modelled at the day level (level 1) and the person level (level 2). Because of power restrictions, we could not analyse all sleep parameters in one model; therefore, we tested objective and subjective sleep parameters separately. Moreover, for both objective and subjective sleep, we distinguished between a general model, containing SE (for objective sleep) or SQ (for subjective sleep) and sleep duration (Figure 6.2), and a specific model including three aspects of sleep quality: SOL, NWAK, and WASO (Figure 6.3). The following sleep outcomes were specified in each of the models: Model 1 (general objective model): SE and objective sleep duration (Figure 6.4); Model 2 (specific objective model): objective SOL, NWAK, and WASO (Figure 6.5); Model 3 (general subjective model): SQ and subjective sleep duration; and Model 4 (specific subjective model): subjective SOL, NWAK, and WASO. All models included day-level stress as the independent variable, day-level PC as the mediator, and day-level sleep as the dependent variable. Relations between stress and PC, as well as between PC and sleep parameters, were estimated. In addition, the direct path from stress to the sleep parameters was modelled. All paths between stress, PC, and sleep parameters were estimated on level 1 and level 2. In all models, measurement occasion (recoded into values ranging from 0 to 7) was entered as a within-level control variable. Age and gender were entered as between-level control variables. The control variable age was centered at the grand mean and gender was entered as a dummy variable. So as not to overcontrol the models, control variables were specified only as predictors of the sleep parameters. Objective sleep data of one participant on one occasion was removed, as the SenseWear armband did not properly record all sleep data.

6.3 RESULTS

6.3.1 Descriptive statistics and correlations

All means, standard deviations, and correlations are presented in Table 6.1. Across all time points, average stress scores were low to moderate. However, stress increased leading up to the defence ($F(3, 123) = 7.43$, $p < .001$, $\eta_p^2 = .15$) (cf. Van Laethem et al., 2016) and decreased significantly (t (41) = 7.48, $p < .001$) comparing the day directly before the defence ($M = 5.24$, $SD = 0.25$) to the day after the defence ($M = 3.00$, $SD = 0.21$), indicating that the PhD dissertation defence was indeed a stressful event. Regarding objective sleep parameters, the mean score of sleep efficiency was average: respondents slept 87% of their time spent in bed compared to 89% in a previous study (Shambroom et al., 2012). Objectively measured mean TST

Table 6.1 Intercorrelations among study variables

	M	*SD*	ICC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Gender [a] (% male)	20.5%				.01		-.07	.12	.41*	.23	-.23	-.40*	-.34*	-.11	.04	.10	.10	.01
2. Age	35.00	10.01					-.36*	-.15	.04	-.04	.00	-.18	.00	.35*	-.06	-.02	-.01	.20
3. Time																		
4. Stress (1-10)	3.83	1.76				-.38**		.70**	-.01	-.12	.21	.16	-.16	-.36*	-.31*	.18	-.29	-.17
5. PC (0-6)	0.43	0.75	0.35			-.21*	.24**		.20	-.00	.16	-.10	-.29	-.24	-.42*	.33*	-.28	-.19
Objective sleep parameters																		
6. SE (%)	87	0.08	0.43			-.09	.01	-.12*		.64**	-.48**	-.90**	-.97**	-.41*	-.08	.01	-.10	.02
7. TST (in min)	408.82	77.52	0.29			.10	-.06	.06	.37**		-.26	-.45*	-.53**	-.55**	.53**	.42*	.04	.15
8. SOL (in min)	8.89	9.83	0.24			-.02	.03	.10	-.17*	-.05		.27	.35*	-.05	-.03	.44*	-.18	-.08
9. NWAK	10.03	6.21	0.45			.16*	-.10	.09	-.38**	.26**	-.03		.87**	.23	.23	-.08	.11	-.10
10. WASO (in min)	45.23	42.51	0.31			.12	-.02	.11*	-.77**	-.00	-.03	.51**		.43*	.17	-.03	.12	.12
Subjective sleep parameters																		
11. SQ (1-5)	3.77	0.97	0.13			.02	-.03	-.25**	.21**	.02	-.13*	-.12*	-.23**		-.12	-.34	-.10	-.18
12. TST (in min)	453.40	89.20	0.08			.21*	-.12*	.02	-.02	.71**	-.01	.40**	.36**	.05		.05	-.11	-.27
13. SOL (in min)	21.44	33.36	0.13			-.21*	.05	.09	-.18**	-.23**	.12*	.03	.07	-.35**	-.31**		.27	.25
14. NWAK (1-5)	2.54	1.39	0.24			.06	-.09	.10	-.22**	.15*	.13*	.29**	.27**	-.55**	.17*	.14*		.36*
15. WASO (1-5)	2.40	1.14	0.26			-.05	-.03	.17*	-.22**	.15*	.09	.18**	.27**	-.58**	.14*	.12*	.62**	

Note: ICC = intra-class correlation; NWAK = number of awakenings; PC = perseverative cognition; SD = standard deviation; SE = sleep efficiency; SOL = sleep onset latency; SQ = sleep quality; TST = total sleep time; WASO = wake after sleep onset

Above diagonal person-level (n = 44), below diagonal day-level (n = 344); [a] 1 = male, 2 = female; * $p < .05$, ** $p < .01$

score of 7 hours was above average compared to objective TST in other cohorts (~6 hours) (Lauderdale et al., 2006; Shambroom et al., 2012; Vgontzas et al., 2014). Mean objective SOL was 9 minutes, which corresponds to objective SOL in other studies (O'Donoghue, Fox, Heneghan, & Hurley, 2009; Zoccola, Dickerson, & Lam, 2009). The number of objectively measured NWAK was on average 10 awakenings per night, which is similar to previous research (Shambroom et al., 2012). The mean score of objective WASO in our study was higher than objective WASO in another study (Shambroom et al., 2012). Regarding subjective sleep parameters, average sleep quality was fairly good considering the maximum of the measurement scale: respondents scored on average 3.7 on a 5-point scale. Mean subjective TST was higher than objectively measured TST, and also above average compared to previous research (Lauderdale et al., 2006). Mean subjective SOL of 22 minutes was above average compared to other studies (15-19 minutes) (Dillon et al., 2014; Zoccola et al., 2009). Subjectively measured NWAK (one to two times per night) corresponded with previous research (Dillon et al., 2014). Subjective WASO was somewhat lower than in a previous study (Dillon et al., 2014).

Respondents did not have perseverative cognitions at bedtime or during the night on 236 occasions (69.4%). However, on the other 104 occasions (12 data points were missing), participants did have perseverative cognitions about one (22.1%), two (5.6%), three (2.4%), or even four (0.6%) topics. When having perseverative cognitions, respondents were thinking about the dissertation defence (48%), their work (28%), private matters (20%), job insecurity (11%), their sleep patterns (5%), and/or other topics (28%).

Table 6.2 Fit indices of all models

	Fit indices				
	χ^2 *(df)*	RMSEA	CFI	$SRMR_{within}$	$SRMR_{between}$
Model 1 Stress -> PC -> SE/objective TST	6.20 (3)	0.06	0.98	0.02	0.05
Model 2 Stress -> PC -> objective SOL/NWAK/WASO	6.28 (3)	0.06	0.98	0.02	0.05
Model 3 Stress -> PC -> SQ/subjective TST	6.22 (3)	0.06	0.95	0.02	0.05
Model 4 Stress -> PC -> subjective SOL/NWAK/WASO	6.36 (3)	0.06	0.98	0.02	0.04

Note: CFI = comparative fit index; NWAK = number of awakenings; PC = perseverative cognition; RMSEA = root mean square error of approximation; SE = sleep efficiency; SOL = sleep onset latency; SRMR = standardized root mean square residual; TST = total sleep time; WASO = wake after sleep onset

Day-level correlations show that stress was positively correlated with PC and negatively correlated with subjective TST. However, stress was not significantly correlated with any of the other objective or subjective sleep indicators. PC was negatively correlated with objective SE and subjective SQ. Positive correlations of PC with objective and subjective WASO were found. Correlations between sleep parameters showed that objective SE and subjective SQ correlated positively. Moreover, objective TST, SOL, NWAK, and WASO were correlated with their subjective counterparts, but the strength of these correlations varied from small to large.

Inspection of the intra-class correlations revealed that about one-third the variance in all measured variables was at the person-level (between-person), and indicated that most variance was at the day level (within-person). Based on the intra-class correlations, we can assume that using the multilevel approach is justified.

Taking into account recommendations of Hu and Bentler (Hooper et al., 2008; Hu & Bentler, 1999), all four multilevel models fitted the data well (see Table 6.2 for all fit indices). Below, we first present results for day-level stress in relation to objective and subjective sleep parameters. Because day-level relations were the focus of this study and all person-level results were nonsignificant (except for the person-level relationship between stress and PC: .69, $p < .001$), we present only the day-level (within-person) findings. We will conclude the results by presenting the day-level (within-person) mediation analyses. To facilitate comparison of effects, standardized estimates are reported.

6.3.2 Day-level stress in relation to subsequent objective and subjective sleep parameters (Hypotheses 1 and 2)

Objective sleep parameters

Investigation of model 1 showed that, on the day level, stress was not directly related to sleep efficiency [estimate = -.01, not significant (*ns)]*, or to objective TST (i.e., sleep duration; estimate = -.05, *ns).* In model 2, including the separate sleep quality dimensions objective SOL, NWAK, and WASO, it was shown that none of the sleep dimensions were affected by stress on the day level (SOL: estimate = -.08, *ns*; NWAK: estimate = -.08, *ns*; WASO: estimate = .01, *ns*).

Subjective sleep parameters

In model 3, stress was not predictive of subjective estimations of sleep quality (estimate = .03, *ns*), or subjective TST (i.e., sleep duration; estimate = -.06, *ns*). Inspecting model 4 containing the separate sleep quality dimensions subjective SOL, NWAK, and WASO showed that stress was not directly related to any of the

sleep dimensions on the day level (SOL: estimate = .02, *ns*; NWAK: estimate = -.10, *ns*; WASO: estimate = -.09, ns).

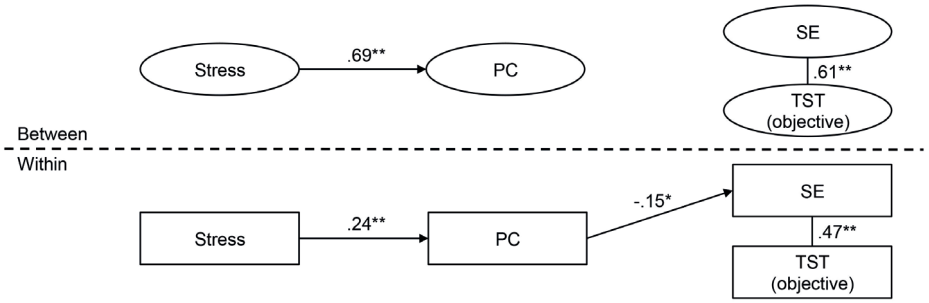

Figure 6.2 Model 1 (general objective model): day-level stress, day-level perseverative cognition (PC), sleep efficiency (SE), and objective sleep duration (TST)
Note: To improve clarity, control variables and insignificant paths are not depicted in this figure

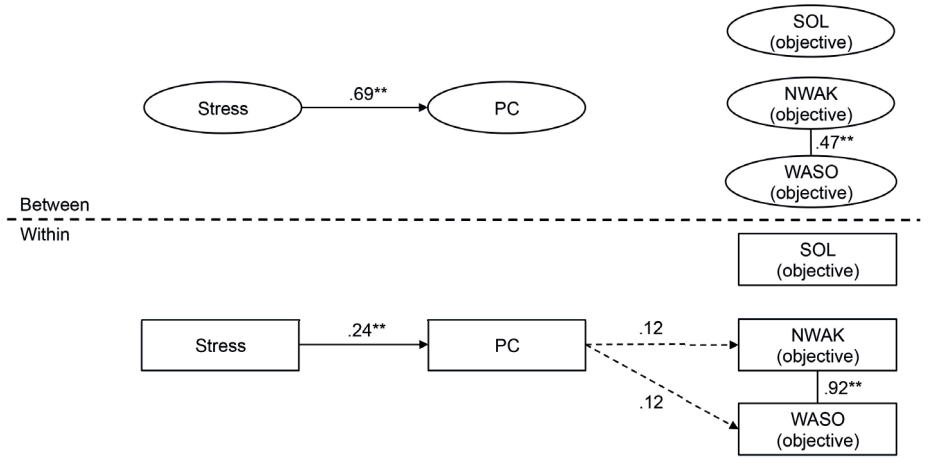

Figure 6.3 Model 2 (specific objective model): day-level stress, day-level perseverative cognition (PC), objective sleep onset latency (SOL), number of awakenings (NWAK), and wake after sleep onset (WASO)
Note: To improve clarity, control variables and insignificant paths are not depicted in this figure

6.3.3 PC as a mediator linking stress to sleep (Hypotheses 3 and 4)

Stress in relation to PC

All models revealed a relationship between day-level stress and subsequent PC: estimate = .24, $p < .001$.

PC in relation to objective and subjective sleep parameters

Regarding the day-level association between PC and objective sleep parameters, Model 1 showed that PC was negatively related to sleep efficiency (estimate = -.15, $p < 0.05$), but not related to objective TST (objective sleep duration: estimate = .07, *ns*). In model 2, PC was not associated with objective SOL (estimate = .10, *ns*), but its relation with objective NWAK and WASO was nearly significant (NWAK: estimate = .12, $p = .059$; WASO: estimate = .12, $p = .055$).

Concerning the relation of PC with subjective sleep parameters, model 3 revealed that PC was predictive of sleep quality (estimate = -.24, $p < .001$) but not of

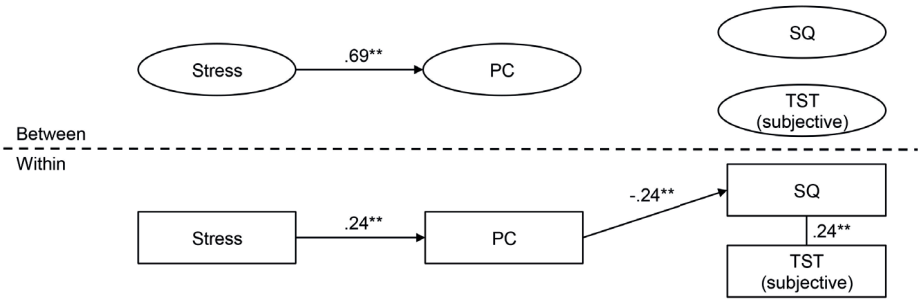

Figure 6.4 Model 3 (general subjective model): day-level stress, day-level perseverative cognition (PC), sleep quality (SQ), and subjective sleep duration (TST)
Note: To improve clarity, control variables and insignificant paths are not depicted in this figure

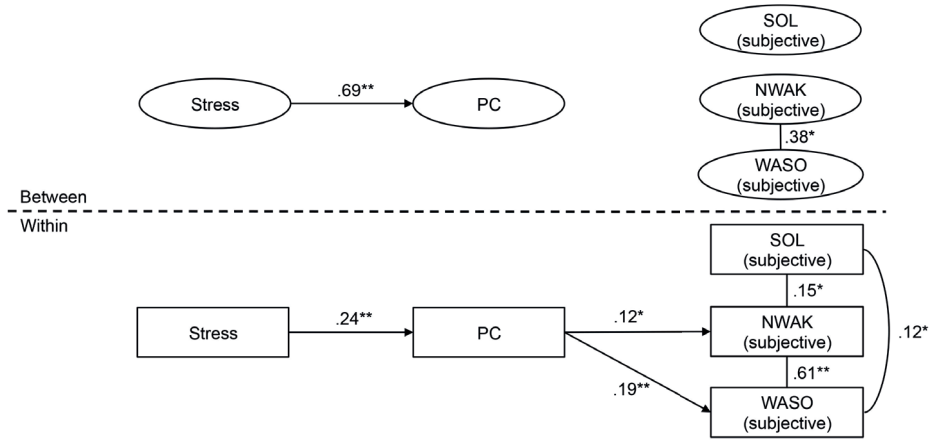

Figure 6.5 Model 4 (specific subjective model): day-level stress, day-level perseverative cognition (PC), subjective sleep onset latency (SOL), number of awakenings (NWAK), and wake after sleep onset (WASO)
Note: To improve clarity, control variables and insignificant paths are not depicted in this figure

subjective TST (subjective sleep duration: estimate = .05, *ns*). Model 4, including the subjective sleep quality dimensions, showed that PC was not associated with subjective SOL (estimate = .09, *ns*), but was related to subjective NWAK (estimate = .12, $p < .05$) and WASO (estimate = .19, $p < 0.01$).

Mediation analysis

Mediation effects were calculated only when conditions for mediation were satisfied, which means that there had to be a day-level relationship between stress and PC as well as day-level relations between PC and a given sleep parameter. Modern assumptions of mediation do not require a direct relationship between the independent and dependent variables (i.e., stress and sleep) (Hayes, 2009, 2013). Hayes (Hayes, 2009), for instance, argued that multiple mediators may be responsible for an effect from an independent variable to a dependent variable, and that if relations with those mediators are in opposite directions, a direct effect from the independent to dependent variable may be insignificant. Thus, in the present study, a direct relationship between stress and sleep may be absent because the relationship is not only mediated by PC but also by another, opposing mediator. One example of such a mediator could be social support from one's spouse or another family member (cf. Pow, King, Stephenson, Delongis, 2016). After experiencing high day-level stress, one may long for and receive social support at home, which may lead to better sleep.

Mediation conditions were satisfied for objective sleep efficiency, subjective sleep quality, subjective NWAK, and subjective WASO. Since the relation between PC and objective NWAK as well as the relation between PC and objective WASO was marginally significant, we also performed mediation analyses for these outcomes. Indirect effects were calculated with the IND statement. In addition, Bayesian estimates were computed, but were almost identical to estimates calculated with the IND command. Therefore, the Bayesian estimates are not reported here. Moreover, only within-person day-level results are reported, as all between-level results were nonsignificant. (Between-level results and Bayesian estimates can be obtained from the first author upon request.)

There was a significant mediation effect of PC linking stress and objective sleep efficiency on the day-level [estimate = -.03, 95% confidence interval (CI) = -.07, -.002[, but no significant mediation effects with the outcome objective NWAK (estimate = .03, 95% CI = -.004, .06) and objective WASO (estimate = .03, 95% CI = -.003, .06).

For subjective sleep quality, we found a significant indirect effect on the day-level from stress, through day-level PC to day-level sleep quality (estimate = -.06, 95% CI = -.09, -.02). PC did not act as a mediator between stress and subjective NWAK (estimate = .03, 95% CI = -.003, .06). Finally, PC did act as a mediator linking

stress to subjective WASO on the day-level (estimate = .05, 95% CI = .01, .08). All significant day-level mediation findings were in the expected direction (higher stress → more PC → more unfavourable sleep).

6.4 DISCUSSION

In an effort to verify whether changes in day-level stress are related to within-person variations in objective and subjective sleep, and to assess whether day-level perseverative cognition (PC) serves as a mediator, we followed PhD students leading up to and following a stressful, but predictable event - namely, their dissertation defence. Our findings showed that daily stress was not directly related to objective sleep or to subjective sleep. However, day-level stress was strongly related to subsequent PC, and within-person fluctuations in PC, in turn, were related to day-level objective measurements of sleep efficiency (SE), to objectively and subjectively measured number of awakenings (NWAK), to objectively and subjectively measured time awake after sleep onset (WASO), and to subjective estimations of sleep quality. PC acted as a mediator linking stress with sleep efficiency, sleep quality, and subjective WASO.

6.4.1 Stress in relation to objective and subjective sleep

The findings of this study provide insight into how stress and sleep are related in the daytime. The finding that within-person day-level variations in stress did not predict day-level objective or subjective sleep was contrary to the expectations and does not support hypotheses 1 and 2. Our results partly correspond with previous research, but findings on day-level relations between stress and sleep so far have not been consistent. For instance, one study found that daily stress is related to subsequent sleep efficiency and objective WASO, but not to TST or NWAK (Åkerstedt, Kecklund, & Axelsson, 2007). Another study (Dahlgren et al., 2005), however, showed that higher day-level stress was related to objective TST, but not to sleep efficiency or subjective sleep quality. One explanation for the absence of consistent evidence for a direct relationship between stress and sleep on the day level could be that PC indeed acts as a mediator. Apart from our study findings, research by Brosschot, Van Dijk, and Thayer (2007) supports this idea, as it showed that the effects of daily stressors on heart rate and heart rate variability during the subsequent night were mediated by worry duration.

6.4.2 The mediating role of PC

Even though we did not detect direct effects of stress on sleep, stress was related to some sleep parameters via PC. These results partly support hypotheses 3 and 4, and extend the PC hypothesis to the day level. More specifically, our study showed that higher day-level stress was related to more daily PC, which, in turn, predicted lower sleep efficiency, lower sleep quality, higher objective and subjective NWAK and higher objective and subjective WASO. PC acted as a day-level mediator between stress on the one hand, and sleep efficiency, sleep quality, and subjectively measured WASO on the other hand.

PC did predict all sleep variables except SOL. Contrary to the expectations, PhD students who had perseverative cognitions did not take longer to fall asleep. Perhaps participants were exhausted and able to fall asleep as normal even though they were somewhat stressed and had perseverative cognitions at bedtime. In line with this assumption, our data show that participants reported moderate to high levels of fatigue. Mean scores of fatigue ranged from 5.89 to 6.91 on a 10-point scale. However, participants may have slept more lightly during the night due to increased stress-levels, or ongoing unconscious PC during the night (Brosschot, Verkuil, & Thayer, 2010), which may have been related to more frequent and longer awakenings. This line of reasoning converges with our finding that stress is related to lower sleep efficiency, lower sleep quality, and longer time awake during the night as well as increased PC.

Our findings are partly in line with previous research on person-level relations among (work-related) stress, PC, and sleep (Brosschot, 2010; Van Laethem et al., 2015). Moreover, the detected mediation effects of PC are in line with the study by Brosschot and colleagues (2007) and a previous study on day-level relations among distressing work shifts, PC, and sleep (Radstaak et al., 2014b).

Previous studies have often reported divergent findings for subjective and objective measures of, for instance, NWAK and WASO (Landry et al., 2015; Unruh et al., 2008). It is noteworthy that our findings on subjective and objective sleep parameters converge to a large extent. It seems that, in our study, objective and subjective measures of sleep lead to the same conclusions on relations with stress and PC, which may indicate that objective and subjective measures represent similar aspects of sleep within the study population.

6.4.3 Strengths and limitations of the present study

We believe that the present study has several strengths. First, even though previous research has shown that sleep fluctuates on the day level, only a few studies so far have examined possible causes of poor sleep on the day-level. This study fills this gap and gives more insight into day-level sleep and important related

underlying mechanisms. A second strength is the thorough measurement of sleep by means of both subjective and objective methods. A final strength is the field setting of this study, which allows observation of PC and sleep in a naturally occurring, stressful situation, as opposed to a laboratory setting with artificially induced stress, thereby increasing the validity and generalizability of our results.

In addition, we have to note three limitations of the current study. First, PC was measured with one multiple-response item, which provides detailed and relevant information about the content of PC but lacks an optimal assessment of its duration or intensity. We believe that it is reasonable to assume that PC about more topics does indirectly infer that one also engages in longer, and thus more intensive, PC. Nonetheless, future research may benefit from including extra items measuring duration and intensity of PC. Another shortcoming of the PC measure used in the present study is that the item simultaneously assessed PC during bedtime and during the night. Thus, PC during bedtime and during the night could not be separated, and conclusions about the causal order of relationship between PC and sleep could not be drawn. In addition to the traditional direction of causality (i.e., more PC at bedtime leads to poor sleep), reversed causation from poor sleep to increased PC during the night could possibly explain our findings as well. We strongly encourage future researchers to separately assess PC at bedtime and PC during the night and to additionally examine reversed causation. A second limitation of this study was the rather low number of participants, which did not permit us to distinguish among separate PC topics and their separate influence on sleep. Future studies would do well to include more participants and may investigate the content of PC (e.g., home-related PC and work-related PC) in relation to sleep. Additionally, including more participants would increase statistical power and would enable researchers to examine person-level variables from the general questionnaire such as trait PC or other personality factors in relation to the stress-sleep relationship. Another issue related to the low number of participants concerns the unexpected low-to-moderate stress levels. We assume that our study sample was rather selective, predominantly containing relatively relaxed PhD students. The sample of PhD students reported generally favourable scores on stress, PC, and sleep, which supports our assumption regarding a selective study sample. In addition, most nonparticipating PhD students reported high feelings of stress, high negative anticipation, and inability to cope with stress as the most important reasons for not participating in the study. Thus, the sample may be nonrepresentative, which has consequences for the external validity and generalizability of our results. Our findings on the relations among stress, PC, and sleep may be valid only for female, generally highly educated individuals who are able to cope well with stressful situations. However, it should be noted that this selection effect

raises the odds for underestimation instead of overestimation of the actual effects. In a representative sample, the relations between stress, PC, and sleep would likely be stronger, implying that our conclusions about the presence of day-level relations among stress, PC, and sleep are valid. Future research should take this into account and may include a more heterogeneous sample in terms of gender, education, and especially stress-coping skills. A final limitation is that the time lags in this study varied from three weeks in between measurements (e.g., Pre 1 to Pre 2) to two days between measurements (e.g., Pre 3 to Pre 4). In future research, it would be interesting to focus on the week before a stressful event and to compare high-stress groups with low-stress groups on day-level variations in PC in relation to day-level sleep, rather than to focus on a longer period. Moreover, as daytime napping and daytime sleepiness are closely related to sleep (Dijk, 2015), future studies might also examine daytime napping and daytime sleepiness and their role in the relations among stress, PC, and sleep.

6.4.4 Theoretical and practical implications

This study contributes to the literature by providing evidence for day-level relations among stress, PC and sleep parameters and by extending existing research on the PC hypothesis. Our findings suggest that PC plays a relevant role as an underlying mechanism linking stress and sleep on the day level. It seems that, in stressful situations, individuals worry more and simultaneously experience an increase in sleep problems. Therefore, detachment from work or other stressful issues is important to avoid or to minimize PC, which may ultimately benefit sleep and health. Employers may assist their employees by providing sufficient opportunities for detachment during work (e.g., with well-timed work breaks) as well as sufficient recovery opportunities between working periods (e.g., by limiting overtime work and providing sufficient leave days).

In summary, the present study suggests that day-level stress is related to subsequent day-level PC, which in turn may be a risk factor for subsequent day-level sleep problems.

Acknowledgements

We thank Jacqueline Berns for her assistance during the recruitment of participants.

Chapter 7

General discussion

The studies in this dissertation provided evidence for reciprocal adverse relations between work-related stress(ors), (work-related) perseverative cognition (PC), and sleep. PC was defined as being cognitively preoccupied with past or future stressors (Brosschot et al., 2006). This dissertation showed that PC acts as a mediator in between work stress(ors) and sleep both in the short term and long term, which supports the role of PC as an underlying mechanism of the stress-sleep relationship. Moreover, this dissertation shed a first light on the 'short term' time course of stress and sleep in the face of an upcoming stressful event. Additionally, insight into the 'long term' time course of stress, PC, and sleep, when being chronically exposed to high job demands for at least four years, was provided.

To begin the in-depth discussion of this dissertation, I will first shortly summarize the main findings of the separate studies. Subsequently, these findings will be integrated and placed within the theoretical framework of this dissertation. Thereafter, strengths, limitations and a future research agenda will be considered. Finally, I will conclude my dissertation by discussing practical implications of the findings and providing an overarching conclusion.

7.1 SUMMARY OF MAIN FINDINGS

The main objectives of this dissertation were to examine (i) the temporal relations between work-related stress(ors), PC, and sleep, (ii) the role of PC as a potential underlying mechanism in the stress-sleep relationship, and (iii) the development of stress and sleep over time. To achieve these objectives, five empirical studies were conducted that are discussed in chapter 2 to chapter 6.

In **chapter 2**, a systematic review of the scientific knowledge about the reciprocal associations between psychosocial work stressors and sleep quality was presented, with a focus on longitudinal and intervention studies. The review showed that previous research found some evidence for a negative relation between job demands and subsequent sleep quality, and for a positive relation between job control and subsequent sleep quality. However, a quality assessment of present scientific research also showed that (high-quality) research into the temporal associations between work stressors and sleep quality is scarce. Moreover, most previous research did not examine reciprocity between stressors and sleep, and hardly any attention was paid to potential underlying mechanisms linking stress(ors) to sleep, such as PC. Addressing the limitations of previous research, we performed two high-quality long-term longitudinal studies.

In chapters 3 and 4, two large scale full-panel longitudinal studies were presented with the aim to unravel temporal relations between work stress(ors), work-related

PC, and sleep quality, with special attention for reciprocal associations, indicating mutual influences over time. Moreover, it was examined whether work-related PC is an underlying mechanism in the proposed stress(or)-sleep relationship. In **chapter 3**, a two-wave full-panel study among a large and heterogeneous sample of the Dutch working population provided insight into the temporal relations between work-related stress, work-related PC, and sleep quality. Work-related stress and work-related PC were positively and reciprocally related and work-related PC and sleep quality were negatively and reciprocally related. Moreover, we found a negative, reversed relation between work-related stress and sleep quality (i.e., lower sleep quality was associated with higher subsequent experience of work-related stress). Most importantly, work-related PC was found to fully mediate the relationship between work-related stress and subsequent sleep quality. In **chapter 4**, a three-wave full-panel study allowed us to confirm the reciprocal relations found in chapter 3 and extended these results to job demands (as compared to work-related stress). In this study, we distinguished between two important sleep quality dimensions: sleep disturbances and awakening problems. The association between job demands and work-related PC was positive and reciprocal, as was the relation between work-related PC and poor sleep quality (i.e., sleep disturbances and awakening problems). Work-related PC served as a mediator in both the normal and reversed relation between job demands and sleep disturbances, and in the normal and reversed relation between job demands and awakening problems. Moreover, employees reporting continuous high job demands across all waves reported higher sleep disturbances, awakening problems, and more work-related PC compared to employees with stable moderate- or stable low job demands.

The first three studies focused on long-term processes. In chapters 5 and 6, short-term (i.e., day-level) processes were emphasized. The chapters represent two articles based on the same longitudinal diary-based study, in which we followed a group of PhD students awaiting and following a stressful life event (i.e., their public dissertation defence). In **chapter 5**, the focus was on the development of stress, fatigue, and sleep quality leading up to and following that stressful life event. Moreover, day-level relations between anticipation on the one hand, and stress, fatigue, and sleep quality on the other hand, were examined. Stress levels increased leading up to the defence and decreased rapidly following the defence. Fatigue remained unchanged leading up to the defence, but did increase immediately following the defence, before slowly decreasing thereafter. Sleep quality did not decrease leading up to the defence, but did improve directly following the defence. One month before the defence, stress levels were already elevated compared to one month post defence. Day-level stress was adversely affected by

day-level negative anticipation and favourably by day-level positive outcome expectancy regarding the defence. Positive outcome expectancy was an important predictor of sleep quality on the day-level. In **chapter 6**, we took advantage of the natural within-person variation created by the stressful life event and examined prospective day-level relations between stress, PC, and objective and subjective sleep parameters. Moreover, we investigated whether PC was an underlying mechanism of the stress-sleep relationship on the day-level. Day-level stress was not directly related to subsequent objective or subjective sleep indicators. However, day-level stress was associated with day-level PC, and daily PC was related to several day-level objective sleep parameters (i.e., sleep efficiency, marginally to number of awakenings and wake after sleep onset), and to several day-level subjective sleep parameters (i.e., sleep quality, number of awakenings and wake after sleep onset). Day-level PC functioned as a mediator linking day-level stress to day-levels of several sleep parameters (i.e., subjective sleep quality, objective sleep efficiency, and subjective wake after sleep onset).

In the next section, I will integrate the findings of the separate studies to attain the main objectives guiding this dissertation.

7.2 INTEGRATED DISCUSSION OF FINDINGS

7.2.1 Temporal relations between work-related stress(ors), PC, and sleep

The first research question of this dissertation was whether work-related stress(ors), PC, and sleep are reciprocally related over time. This research question was examined in three studies of this dissertation (chapters 2-4). Additionally, chapter 6 focused on an element of this research question, i.e. only normal causation from day-level work stress, to PC, to sleep quality. First, the results on the direct relation between work-related stress(ors) and sleep are presented. Afterwards, the findings on the relation of work stress(ors) with PC, and the relation of PC with sleep are discussed.

Relations between work-related stress(ors) and sleep

Regarding the direct relationship between work-related stress(ors) and sleep quality, we found inconsistent evidence. The systematic review on psychosocial work characteristics and sleep quality showed that most previous research had only investigated the traditional direction of causal precedence (i.e., normal causation: job demands -> sleep quality). Based on the existing literature, we concluded that there was evidence for a negative relation between job demands and sleep

quality and for a positive relation between job control and sleep quality. However, findings of the individual studies within the review varied. This inconsistent evidence for a direct association between work stress(ors) and sleep is in line with the findings of the longitudinal studies of this dissertation: we found inconsistent evidence for a relation in the traditional direction from stress to sleep as well as for the reverse path from sleep to stress(ors). Results of the two-wave longitudinal study (chapter 3) on work-related stress, work-related PC, and sleep quality only revealed a negative, reversed direct relation between work-related stress and sleep quality (sleep quality -> work-related stress). There was no evidence for traditional normal causation (directly linking work stress to sleep quality). In the three-wave longitudinal study (chapter 4) on job demands, work-related PC, and sleep quality reciprocal, temporal relations between job demands and both sleep quality dimensions (i.e., sleep disturbances and awakening problems) were found. However, when including work-related PC in the same model, the direct, normal relation between job demands and subsequent sleep disturbances disappeared. Our findings regarding job demands and sleep disturbances correspond with recent research, which also found inconsistent results. Some studies have reported positive, reciprocal relations between job demands and sleep disturbances (Åkerstedt et al., 2015), other studies were not able to reveal a relation between these two concepts (Magnusson Hanson et al., 2011). Regarding awakening problems, some previous research has found no relation between job demands and awakening problems (Magnusson Hanson et al., 2011), yet a recent study did reveal a positive, reciprocal relation (Garefelt et al., 2016).

The findings of the longitudinal diary-based study presented in chapter 6 provide insight into how stress and subsequent sleep are related on the day-level and are in line with the inconsistent findings regarding the direct relation between stress and sleep found in both long-term longitudinal studies (chapters 3 and 4). These results partly correspond with previous research, as findings on day-level relations between stress and sleep so far have not been consistent (Åkerstedt, Kecklund, & Axelsson, 2007; Dahlgren et al., 2005).

It is noteworthy that the previously mentioned former studies on job demands and sleep disturbances (Åkerstedt et al., 2015) and on job demands and awakening problems (Garefelt et al., 2016), which found reciprocal relations between job demands and subsequent sleep disturbances and awakening problems, have used (some) waves of the same cohort as were used in our study. However, contrary to our research, these studies did not account for work-related PC in their analyses, which might explain the slightly different findings of these studies regarding job demands and sleep quality. Previous research has suggested that work-related PC might be an important mediator of the stress-sleep relationship

(Åkerstedt, 2006). For both of our long term longitudinal studies, we performed additional analyses, which demonstrated that work-related stress(ors) and sleep quality were indeed negatively and reciprocally related when excluding PC from the model. Including work-related PC while evaluating the stressor-sleep relationship and not finding a direct relationship between stress(or) and sleep is a strong indication that work-related PC is indeed a key mediator variable in this relationship.

Relations between work-related stress(ors) and PC, and between PC and sleep

Both long-term longitudinal studies presented in this dissertation showed that work-related stress(ors) and work-related PC were positively and reciprocally related, indicating that work-related stress(ors) were related to increased future work-related PC, and also that work-related PC was related to subsequent increased work stress(ors). Additionally, a negative, reciprocal relation between work-related PC and sleep quality was revealed. Work-related PC was related to reduced future sleep quality and lower sleep quality was related to increased subsequent work-related PC. This was true for both dimensions of sleep quality. Work-related PC was associated with a subsequent increase in sleep disturbances and awakening problems, while sleep disturbances and awakening problems were simultaneously related to an increase in future work-related PC. Work stress(ors), work-related PC, and sleep quality were reciprocally related over one year, but also over as long as two years.

The longitudinal diary-based study showed that day-level stress was related to day-level PC, and day-level PC, in turn, was related to subsequent day-level sleep (i.e., lower sleep efficiency, lower subjective sleep quality, a higher objective and subjective number of awakenings and a longer wake after sleep onset). Most of our findings regarding PC in relation to work stress(ors) and sleep are in line with previous studies (Åkerstedt et al., 2012; Cropley et al., 2006; Kompier et al., 2012) and underline the relevance of examining work-related PC as potential mediator in the association between stress(ors) and sleep.

One important remark regarding longitudinal research, and especially longitudinal health research, is that effect sizes are generally rather small (β's in our studies ranged from .03 to .15). However, small effect sizes do not imply small effects in relative terms. Changes over time within the study variables are accounted for in structural equation modelling and explain a large part of the variance (Van Hooff et al., 2005). Moreover, work-related stress(ors) and work-related PC are only a few of many factors that have an impact on sleep quality (cf. Zapf, Dormann, & Frese, 1996). Other important antecedents of poor sleep are, for instance, health, stressors in private life, and alcohol use (Lallukka et al., 2010; Roehrs & Roth, 2001).

Thus, although our studies report small effect sizes in absolute terms, these effects should not be trivialized.

To summarize our findings on the interrelations between work-related stress(ors), PC, and sleep, we found supporting evidence for reciprocal relations between these concepts. See Table 7.1 for an overview of findings per research question and chapter. The direct relation between work stress(ors) and sleep is not straightforward when concurrently examining work-related PC, hinting toward an important role of PC as a mediator in the stress-sleep relationship.

Table 7.1 Overview of findings per research questions and chapter

Research Question		Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6
1	Are work-related stress(ors), perseverative cognition, and sleep reciprocally related?	+[a]	+	+		/[b]
2a	Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *long* term?		+	+		
2b	Does perseverative cognition have a mediating role in the association between work-related stress(ors) and poor sleep in the *short* term?					+[c]
3a	How do work-related stress(ors) and sleep develop in the *long* term?			/		
3b	How do work-related stress(ors) and sleep develop in the *short* term?				/	

Note: + = evidence supports expectations; 0 = evidence does not support expectations; / = evidence partially supports expectations; [a] = only work-related stressors and sleep quality were examined; [b] = only the normal causation relation was examined; [c] = for some of the subjective and objective sleep parameters

7.2.2 PC as an underlying mechanism of the stress-sleep relationship

The second research question of this dissertation was whether PC is a mediating mechanism in-between work-related stress(ors) and sleep. Both the long term longitudinal studies (chapters 3 and 4) as well as the diary study (chapter 6) of this dissertation found that PC was a mediating mechanism in the pathway from stress(or) to sleep quality. These findings support the PC hypothesis (Brosschot, 2010; Brosschot et al., 2006), which states that a continuous mental representation

of stressors may cause prolonged physiological activation, and consequently poor sleep quality, rather than (or in addition to) the stressors themselves. Moreover, the results of the longitudinal diary-based study extend the PC hypothesis to the day-level and are in line with a previous diary-based study on day-level relations between distressing work shifts, PC, and sleep (Radstaak et al., 2014b).

Chapter 4 showed that the mediating role of PC seems to apply to both sleep disturbances (i.e., lack of sleep continuity) and awakening problems (i.e., being insufficiently restored). Chapter 6 (day-level study) showed that the mediating role of PC was found not only for subjective measures of sleep disturbances but also extends to objective measures of sleep quality (i.e., objective measures of sleep efficiency). In addition to the role of PC in the pathway from stress(or) to sleep quality (normal causation), in chapter 4, we also examined the role of PC in the reverse pathway from sleep quality to work stressors (job demands). This study was among the first to indicate that PC also mediates the reverse relation from sleep quality (i.e., sleep disturbances and awakening problems) to job demands. The finding that work-related PC served as a mediator in the reversed relation between sleep quality and job demands extends the PC hypothesis and lends support to the stressor creation hypothesis (Bowling & Jex, 2013; De Lange et al., 2005; Spector et al., 2000). The core assumption of the stressor creation hypothesis is that next to the traditional causal relation (e.g., stress has an influence on subsequent sleep), a reversed causal relation is plausible as well. Poor sleep, for instance, may lead to an increase in PC and (perceived) stressors. *Actual* job demands may increase in response to poor sleep because one has to repeat certain tasks as a result of daytime sleepiness, (cognitive) failures and low performance. Alternatively, one may be less energetic due to fatigue and consequently may *perceive* the same demands as being increased.

It is noteworthy that previous studies have often reported divergent findings for objective and subjective measures of sleep parameters (Landry et al., 2015; Unruh et al., 2008; Westerlund et al., 2016), whereas our findings on objective and subjective sleep parameters converge to a large extent. It seems that, in our study, objective and subjective measures of sleep lead to the same conclusions on relations with stress and PC, which may indicate that objective and subjective measures represent similar aspects of sleep within our study population.

To summarize, we can conclude that PC indeed seems to be an important underlying mechanism in the short term as well as long term reciprocal relationship between stress(ors) and sleep.

7.2.3 Development of stress and sleep over time

The third research question concerned the development of stress and sleep over time. In the studies presented here, we were able to shed some light on the time course of stress and sleep in both the long- and the short term. Regarding the long-term development of stress and sleep, results showed that employees with continuous high job demands over a period of four years experienced lower sleep quality (i.e., more sleep disturbances and awakening problems) and higher work-related PC, compared to employees with continuous moderate and low job demands. However, sleep quality did not decrease and work-related PC did not increase over time for individuals reporting stable high job demands. It could be that most workers with continuous high job demands already experienced high job demands before entering the study and the accumulating stress-effects of chronic job demands may have reached their maximum.

In the short term, a group of individuals awaiting a stressful life event reported already elevated stress four weeks before the stressful event took place. In the weeks leading up to the stressful event, stress increased even more, however, afterwards stress levels quickly dropped. Sleep quality was rather high and remained more stable leading up to and following the stressful event and only increased slightly following the stressful event, indicating adequate recovery throughout the period in which they were anticipating the stressful event. The results regarding the long-term and short-term development of stress, PC and sleep are mostly in line with Effort-Recovery theory (Meijman & Mulder, 1998) and Allostatic Load theory (McEwen, 1998), which provide a theoretical understanding of the development of stress and sleep problems. If recovery is incomplete over a prolonged period (e.g. due to PC and/or continuously high demands), negative load effects (e.g., fatigue or elevated heart rate) may accumulate and become chronic, resulting in allostatic load (Geurts & Sonnentag, 2006; McEwen, 1998). The longitudinal study of this dissertation examining this continuous exposure to stressors (i.e., high job demands) shows that constantly stressed or taxed employees indeed suffer from more sleep complaints and engage in more work-related PC compared to employees with moderate or low exposure to stress or demanding work characteristics.

The studies performed in this dissertation provide a partial answer to the question how stress and sleep develop over time. If one is stressed by work or other important, stressful events for a prolonged period (from months to several years), stress levels are heightened but seem to stabilize at some point. At the same time, PC and sleep complaints remain stable as well. Only after the stressor has diminished or disappeared (cognitively), sleep quality improves again.

7.3 STRENGTHS, LIMITATIONS, AND FUTURE RESEARCH AGENDA

7.3.1 Strengths

The research presented in this dissertation has several strengths. First, the extensive and systematic review provided an excellent basis for the subsequent studies of this dissertation and guided the following research to not only focus on the traditional 'normal causation' relation, but to also take reversed and reciprocal across time relations into account. Moreover, the review provided a set of quality criteria that can guide future research on this topic (see Appendix C).

A second asset of the studies presented in this dissertation is the use of high-quality research designs such as full-panel longitudinal studies and longitudinal diary-based designs. These designs enable examining reciprocal temporal, short-term as well as long-term relations and permit cautious conclusions about causality (Kompier & Taris, 2011; Taris & Kompier, 2014). Looking into the temporal order of variables, which is facilitated by the use of high-quality multi-wave designs, enabled us to additionally examine PC as an underlying mechanism in the reciprocal stress-sleep relationship, and to investigate the development of stress and sleep over time. Hardly any previous research examined these temporal associations and time course properly.

A third strength of the current dissertation is the field setting of the longitudinal diary-based study. The field design allowed for observation of PC and sleep in a naturally occurring stressful situation, as opposed to a laboratory setting with artificially induced stress. This setting increases the validity and generalizability of our results, which was further enhanced by the thorough measurement of sleep by means of subjective and objective methods.

A fourth asset of the research presented in this dissertation is the use of different time lags from long-term, longitudinal studies with time lags of one to several years, to short-term diary-based studies with daily or weekly measures. As only few studies so far have examined possible causes of poor sleep on the day-level, the diary-based study is especially important in clarifying the relationships between stress, PC, and sleep on the day-level.

Next to these more methodological assets of the current dissertation, a final strength is the contribution to and extension of important theories within the stress and recovery literature. In the research presented, we found evidence for 'normal' and 'reversed' temporal relations between work stress, PC, and sleep. The latter finding regarding reversed causation provides evidence for the stressor creation hypothesis (Bowling & Jex, 2013; De Lange et al., 2005; Spector et al., 2000), in which poor sleep results in either a changed perception of the work environment

(i.e., the gloomy perception mechanism) or in an actual change of the psychosocial work environment (i.e., environmental change mechanism). Moreover, we revealed that PC plays an important role in the relation between work stress and sleep, thus supporting the PC hypothesis (Brosschot, 2010; Brosschot et al., 2006). More specifically, we extended evidence for the PC hypothesis in two ways: first, we found that PC does not only act as a mediator in the normal temporal relation from work stress(ors) to sleep, but also in the reversed relation from sleep to work stress(ors). Second, we found evidence for the PC hypothesis in longitudinal research with long time lags, but also with short time lags, and thus, we were able to extend the PC hypothesis to the day-level. Lastly, the studies in this dissertation provided more insight into the long- and short term time course of stress and sleep.

7.3.2 Limitations and future research agenda

Next to its strengths, this dissertation has some limitations, which should be addressed in future research. A first limitation is the almost exclusive use of self-report measures to measure work-related stress, PC, and sleep (with the notable exception of chapter 6, that included objective measures of sleep). Several potential problems have been mentioned related to the use of self-report measures as, for instance, social desirability or retrospection (Podsakoff & Organ, 1986). Spector (2006), however, has argued that these issues may not be as problematic as previously believed, for instance because mono-method correlations among study variables are often not higher than multi-method correlations. Moreover, some constructs can only be validly measured with self-report measures (i.e., PC) or alternative measures have many drawbacks. Stress, for instance, can be measured in an 'objective' manner (e.g., cortisol), but these measures are rather invasive, expensive, and/or sensitive for confounding variables and 'interpretation' by researchers (the latter reducing the objectivity and validity of 'objective' findings). Moreover, in the case of PC, asking individuals about their perseverative thoughts is the most fitting method, as PC is an introspective phenomenon. Regarding sleep, objective measures may be used (e.g., actigraphy; cf. chapter 6). However, as subjective ratings of sleep quality do not always concur with more objective measures of sleep quality (Landry et al., 2015; Unruh et al., 2008), using a combination of subjective and objective measures to assess health-related concepts will give a more complete overview and improve the validity and generalizability of results. Summarizing, a recommendation for future studies would be to combine self-report measures with objective methods where possible, while keeping in mind that for some measures (e.g., sleep measures) this may be more feasible than for others (e.g., stress). A related issue is the use of single item

measures to assess work-related stress, recovery state, and PC in diary research. Single item measures may not be able to completely assess all individual aspects of a given construct, especially constructs with multiple facets. However, in multi-wave research and especially diary-based research, it is not feasible to use many items to measure concepts, as missing data and dropouts increase when diaries are time-consuming. Additionally, previous research has shown that single item measures can be a valid alternative to multiple-item measures (Van Hooff et al., 2007).

A second limitation is the way in which PC was assessed in the longitudinal diary-based study. PC was measured with one multiple-response item, which provides detailed and relevant information about the content of PC, but lacks an optimal assessment of its duration or intensity. Even though we believe that it is reasonable to assume that PC about more topics does indirectly infer that one also engages in longer, and thus more intensive PC, future research may benefit from including extra items measuring duration and intensity of PC. Moreover, the rather low number of participants did not permit us to distinguish among PC-topics and their separate influences on sleep. Future studies should include more participants and may investigate the content of PC (e.g., home-related PC and work-related PC) in relation to stress and sleep. For further suggestions regarding the design, measurements and analyses of future research, we refer to the quality criteria that were developed as part of the systematic review. In our opinion, these quality criteria constitute a valuable and practical checklist for designing future longitudinal/intervention research (see Appendix C).

A third limitation concerns the conclusions that can be drawn based on the mediation analyses (i.e., from day-level stress to day-level PC to day-level sleep quality) in the longitudinal diary-based study. As the PC item assessed participants' PC during bedtime and/or the night, we cannot untangle whether PC in the evening led to more sleep disturbances during the night (in line with our statistical model), or whether, alternatively, sleep disturbances facilitated PC during nightly awakenings (reverse causation). Even though the mediation analyses performed in chapter 6 has merit, it cannot fully disentangle the temporal order of PC and sleep. As the other chapters of this dissertation show that reciprocal mediation is plausible, future studies should include PC measures that distinguish between bedtime PC and PC during the night and may also examine reversed day-level mediation (in which poor sleep during the night may facilitate and increase PC during the night, which may in turn have a negative impact on stress the following morning).

Another limitation of this dissertation concerns the applied study designs and their limited ability to determine causality. Even though we made progress

in resolving causality, day-level and long-term longitudinal field studies do not allow for definite conclusions in this respect, nor can they disentangle all causal processes. In most longitudinal research, one begins measuring 'at some point in time' in a developing or even already established circular process. This results in the well-known 'hen or egg' dilemma. Moreover, in field studies, not all confounding influences can be excluded, prohibiting definite causal inferences. Other research designs could shed more light on the causal reciprocal processes involved. In an experiment, for example, one could manipulate stress(ors), PC and/or sleep quality, which could provide more insights into the causal processes between work-related stress(ors), PC, and, sleep. Integration of findings from field studies (including high external validity though restricted insight into causality) and laboratory experiments (which allow proper insight into causality but have limited external validity) allows for definite conclusions about the causal relations between stress(ors), PC and sleep in real life.

Finally, our study samples, and in particular the PhD students in the longitudinal diary-based study, may have included a selective sample, with only the more relaxed and/or healthy individuals agreeing to participate. Regarding the PhD-students, this is reflected in their overall favourable scores on stress(ors) and sleep quality. This non-representative sample has consequences for the generalizability of results as these may only be representative for individuals who are able to cope well with stressful situations. However, related to this limitation, it is important to note that our findings may well be an underestimation of the actual effects (cf. healthy worker effect). In a representative sample, also including the more stressed PhD-students and employees, relations between work stress(ors), PC, and sleep would likely be stronger. Future research should take this into consideration and try to include a more heterogeneous sample in longitudinal and especially diary-research, for instance in terms of stress coping skills.

7.4 PRACTICAL IMPLICATIONS

From a more practical perspective, whenever possible, work-directed prevention of stress should be the first step (cf. Kompier, 2003). As such, I first want to emphasize the importance of well-designed and healthy jobs as a means to prevent work stress. Well-designed work is free from exceedingly high levels of stressors that are known to evoke work-related stress and PC (e.g., too high job demands, too low autonomy, bullying) (Kompier, 2003). Periodic organizational risk analyses of the psychosocial work environment, which are mandatory in The Netherlands (cf. Arbeidsomstandighedenwet; van Drongelen & Hofsteenge, 2015), can help to

detect suboptimal work characteristics and be a first step to optimize psychosocial working conditions (e.g., reduce bullying). Regarding the job characteristics examined in this dissertation, we know that a work environment including high, but not too high, job demands in combination with sufficient job control results in challenging jobs (Karasek, 1979; Kompier, 2003) that can be expected to limit PC and contribute to favourable sleep quality, from which both employees and organizations will benefit in terms of employee well-being and performance (Kompier et al., 2012).

In many occupational settings, however, fully eliminating job stressors and work-related stress is impossible. Exposure to high job stressors is an inevitable part of some jobs (e.g., in emergency rooms). Therefore, in addition to work-directed interventions, organizations are advised to additionally provide resources to help their employees to cope with stress and PC. Companies may improve resources at work such as increasing employee-oriented work(time) flexibility to promote recovery (Beckers et al., 2008). Companies may also promote recovery after work and psychological detachment from work, which should lead to reduced PC, by providing, for instance, gym memberships to facilitate exercise, psychological services, training in stress-management techniques and/or sleep hygiene (Budnick & Barber, 2015; Richardson & Rothstein, 2008). Employees who make use of (some of) these resources will potentially be able to better regulate- and recover from inevitable work-related stress (Feuerhahn, Sonnentag, & Woll, 2014). They may also experience better sleep quality, which, in turn, may decrease PC and stress, and increase motivation and productivity, which will benefit the organization in the long run (Driver & Taylor, 2000).

Employees already suffering from (chronic) stress may benefit from worker-directed interventions targeted at reducing stress-related health problems. We recommend *supervisors to initiate* individual meetings with their employees on a regular basis (e.g., once a year) in order to discuss workload and work stress. Stress-related health should also be a topic in staff meetings. Talking about these topics openly should increase awareness of stress-related problems and foster an organizational culture that *allows employees to discuss* stress-related complaints with their supervisors without feeling hesitant to do so. An example of an intervention on a national level is the campaign 'Check your work stress' in the Netherlands, which aimed at raising awareness of stress at work and its consequences, and was supported by the Dutch government. After stress-related health complaints have been identified, an action plan needs to be developed to deal with these complaints. Employees suffering from unavoidable stress may be encouraged to participate in intervention programs as, for example, exercise training for employees showing early signs of burnout. Recent research has shown

that running therapy counteracts feelings of fatigue (De Vries, Van Hooff, Geurts, & Kompier, 2016).

Next to these more general implications concerning high work-related stress and poor sleep, the following implications are in response to the most important findings of this dissertation: reciprocity of the stress-PC-sleep relations and PC as an underlying mechanism of the stress-sleep relationship. First, employees and employers should be informed that high stress is not only related to subsequent reduced sleep quality, but that poor sleep quality is also related to an increase in actual or perceived stress. Knowing that the stress-sleep relation is a two-way street should raise awareness for the possibility that sleep may not only be an outcome of stress, but may also be a point of attack for dealing with problematic stress. Next, employees may attempt to reduce PC and associated stress and sleep complaints by seeking distraction (Gerin et al., 2006) and by undertaking activities that stimulate post-work unwinding (Cropley & Millward, 2009), for example through limiting overtime work (enabled by limiting excessive job demands) and/or through regular exercise (Beckers et al., 2008; Brand et al., 2010; Puterman et al., 2011; Spalding, Lyon, Steel, & Hatfield, 2004). Additionally, Geurts (2014) argues that positive emotions down-regulate the stress response. Thus, inducing positive affective states, for instance by means of pleasurable social interactions with friends and family, may facilitate stress recovery and sleep, and may diminish PC. Another possible method to reduce PC is mindfulness meditation, which has been shown to reduce perseverative modes of thinking (Borders, Earleywine, & Jajodia, 2010; Jacobs et al., 2013; Jain et al., 2007).

7.5 CONCLUSION

The studies presented in this dissertation rendered insight into the temporal interrelations between work-related stress(ors), PC, and sleep, providing evidence for adverse reciprocal relations between these concepts. Importantly, this dissertation has shown that PC is a key underlying mechanism in the reciprocal stress-sleep relationship.

Appendix A-C

Appendix A:
Supplementary material of chapter 2

Appendix B:
Supplementary material of chapter 4

Appendix C:
Supplementary material of chapter 7

APPENDIX A: SUPPLEMENTARY MATERIAL OF CHAPTER 2

Table 1 Complete list of all search terms

Work Characteristics		
Job	Occupation*	Role
Skill	Task	Work*
	In combination with:	
Ambiguity	Downsizing	Psychosocial
Autonomy	Effort	Resources
Bullying	Feedback	Reward*
Boredom	Identity	Satisfaction
Characteristics	Insecurity	Security
Conflict	Load	Social network
Control	Overload	Strain
Coping	Organizational justice	Stress*
Decision latitude	Organizational change	Support
Demands	Pressure	Variation
Discretion	Procedural justice	Variety
	Sleep	
Insomnia	Sleep	
	Longitudinal Design	
Cohort	Long-term	RTC
Intervention	Prospective	Temporal
Longitudinal	Randomized controlled trial	

Table 2 Detailed information on longitudinal studies

Reference	Sample	Measurement of variables	
		Sleep	***Work characteristics***
Åkerstedt et al., 2012 FP, 1 TL: 5 years	3077 mixed occupation, predominantly male, Sweden, rr T1: 93% rr T2: 71%	4 items KSQ (Kecklund & Åkerstedt, 1992), α = .78 - .82	**Job demands** 5 items DCQ (Theorell, 1988), α = .69 - .71 **Job control** 6 items DCQ (Theorell, 1988), α = .31 α significantly lowered by one item, analyses were rerun without this item (α = .61) but same results
Burgard & Ailshire, 2009 FP, 1 TL: 3 years	1101 mixed occupation, US, rr T1: n.r. rr T2: n.r.	1 item CES-D (Radloff, 1977)	**Job control** 3 items decision latitude (Karasek, 1979), α = .61 **Job insecurity** 1 self-constructed item **Negative emotional experiences at work** 1 self-constructed item
De Lange et al., 2009 IP, 3 TL: 3 x 1 year	1136 mixed occupation, Netherlands, rr T1: 84% rr T2: n.r. rr T3: n.r. rr T4: 85% authors report that all response rates were between 84% and 85 %	3 items sleep scale (Appels & Schouten, 1991), α = .65 - .67	**Job demands** 5 items JCQ (Karasek, 1985), α = .65 - .72 **Job control** 8 items JCQ (Karasek, 1985), α = .81 - .83

Statistical analysis		Outcome	Association
Analysis reported	*Confounders*		
1	A, B, C, E, F	**Job demands** **OR = 1.47 (CI 1.15 - 1.89)** Change Low -> high = 1.39 (CI 1.00 - 1.95) High -> high = 1.49 (CI 1.06 - 2.11) High -> low = 1.24 (CI .85 - 1.80)	**-**
		Job control OR = .98 (CI 0.77 - 1.25) Change Low -> high = 1.22 (CI .82 - 1.82) High -> high = 1.09 (CI .79 - 1.51) High -> low = .98 (CI 0.68 - 1.41)	**0**
1	A, C, D, E, F, G	**Job control** OR = .99 (CI .91 - 1.07) Change OR = 1.03 (CI 0.95 - 1.11)	**0**
		Job insecurity OR = 1.09 (CI .89 - 1.32) Change OR = 1.04 (CI .87 - 1.22)	**0**
		Negative emotional experiences at work OR = 1.35 (CI 1.08 - 1.67) Change OR = 1.27 (CI 1.06 - 1.50)	**-**
2	A, C, E	**Job demands** **β (NC) = .07** **Job control** **β (NC) = -.07** SEM model χ^2 (NC) = 73.71	**-** **+**

Edme et al., 2011 IP, 1 TL: 4.2 years	1154 mixed occupation, France, rr T1: 88% rr T2: 52%	5 items NHP (Martini & McDowell, 1975), α not indicated	**Job demands** 9 items JCQ (Karasek et al, 1998), α = .63 **Decision latitude** 8 items JCQ (Karasek et al, 1998), α = .80 **Job strain** job demands/job control **Social support** 8 items JCQ (Karasek et al, 1998), α = .81 **Iso-strain** job demands/job control/social support **Reward** 11 items ERI-Q (Siegrist & Peter, 1996), α = .82 **Effort-reward imbalance** Effort constructed with JCQ
Elovainio et al., 2003 IP, 1 TL: 2 years	3773 mixed occupation, predominantly female, Finland, rr T1: 77% rr T2: n.r.	4 items JSQ (Jenkins et al., 1988), α = .82	**Procedural justice** 8 items Procedural Justice Scale (Moorman, 1991), α = .80 **Relational justice** 7 items Relational Justice Scale (Moorman, 1991), α = .90

1	A, C, E	**Job demands**	
		Men	
		OR = 2.05 (CI 1.33 - 3.16)	**-**
		Women	
		OR = 1.10 (CI .57 - 2.14)	**0**
		Decision latitude	
		Men	
		OR = 1.21 (CI .80 - 1.86)	**0**
		Women	
		OR = .77 (CI .38 - 1.55)	**0**
		Job strain	
		Men	
		OR = 1.88 (CI 1.15 - 3.07]	**-**
		Women	
		OR = 0.56 (CI .25 - 1.25)	**0**
		Social support	
		Men	
		OR = 1.12 (CI .73 - 1.72)	**0**
		Women	
		OR = 0.84 [0.40–1.75]	**0**
		Iso-strain	
		Men	
		OR = 2.40 (CI 1.31 - 4.41)	**-**
		Women	
		OR = .26 (CI .07 - .93)	**+**
		Reward	
		Men	
		OR = 1.60 (CI 1.05 - 2.44)	**+**
		Women	
		OR = .54 (CI .26 - 1.12)	**0**
		Effort-reward imbalance	
		Men	
		OR = 2.02 (CI 1.29 - 3.15)	**-**
		Women	
		OR = 0.70 (CI .32 - 1.53)	**0**
1	A, B	**Procedural justice**	
		OR = 1.25 (CI 1.17 - 1.33)	**+**
		Relational justice	
		OR = 1.18 (CI 1.10 - 1.26)	**+**

Elovainio et al., 2009 IP, on average 1 TL: 12 - 19 years	5209 office employees, England, rr T1: 73% rr T2: n.r.	**Baseline** 2 items from a longer symptoms checklist **Follow-up** 4 items JSQ (Jenkins et al., 1988), α = .63 - .78	**Organizational justice** 5 self-constructed items, α =.62 - .72
Eriksen et al., 2008 IP, 1 TL: 3 months	4771 assistant nurses, predominantly female, Norway, rr T1: 62% rr T2: 87%	1 item from BNSQ	**Job demands** 4 items QPSNordic (Dallner et al, 2000) **Positive challenges** 3 items QPSNordic (Dallner et al, 2000) **Role conflicts** 3 items QPSNordic (Dallner et al, 2000) **Control of work pace** 3 items QPSNordic (Dallner et al, 2000) **Control of decisions in own work situation** 3 items QPSNordic (Dallner et al, 2000) **Social support (from superior)** 3 items QPSNordic (Dallner et al, 2000) **Fairness (from superior)** 3 items QPSNordic (Dallner et al, 2000) **Rewards** 1 item QPSNordic (Dallner et al, 2000) **Feedback** 1 item QPSNordic (Dallner et al, 2000) **Social climate** 3 items QPSNordic (Dallner et al, 2000) **Exposure to threats** 1 item QPSNordic (Dallner et al, 2000) **Exposure to bullying** 1 item QPSNordic (Dallner et al, 2000) α of indices = .57 - .88

3	A, B, C, D, E	Overall sleeping problems	
		Men	
		β = -.06	+
		Women	
		β = -.06	+
		Sleep onset problems	
		Men	
		β = -.04	+
		Women	
		β = -.03	0
		Sleep maintenance problems	
		Men	
		β = -.05	+
		Women	
		β = -.05	0
		Non-refreshing sleep	
		Men	
		β = -.07	+
		Women	
		β = -.06	+
1	A, B, D, E	**Job demands**	
		OR = 1.54 (CI 1.10 - 2.17)	-
		Positive challenges	
		OR = .81 (CI .58 - 1.12)	0
		Role conflicts	
		OR = 1.47 (CI 1.03 - 2.11)	-
		Control of work pace	
		OR = .81 (CI .57 - 1.17)	0
		Control of decisions in own work situation	
		OR = .95 (CI .68 - 1.31)	0
		Social support (from superior)	
		OR = .67 (CI .46 - 1.00)	+
		Fairness (from superior)	
		OR = 1.25 (CI .90 - 1.73)	0
		Rewards	
		OR (rather much) = .74 (CI .54 - 1.00)	+
		OR (very much) = .75 (CI .41 - 1.36)	0
		Feedback	
		OR = 1.27 (CI .80 - 2.04)	0
		Social climate	
		OR = 1.09 (CI .80 - 1.48)	0
		Exposure to threats	
		OR (rather often) = 1.77 (CI 1.27 - 2.46)	-
		OR (very often) = 1.60 (CI .86 - 2.98)	0
		Exposure to bullying	
		OR = .65 (CI .43 - .98)	+

Jansson & Linton, 2006 IP, 1 TL: 1 year	1530 mixed occupation, Sweden, rr T1: n.r. rr T2: n.r.	4 items from BNSQ_ (Partinen & Gislason, 1995) and USI (Liljenberg et al., 1988), α not indicated	**Job demands** 6 items questionnaire by Haynes et al. (1999), α = .77 **Autonomy and control** 6 items questionnaire by Haynes et al. (1999), α = .84 **Influence over decisions** 4 items questionnaire by Haynes et al. (1999), α = .78 **Peer support** 4 items questionnaire by Haynes et al. (1999), α = .84 **Leader support** 6 items questionnaire by Haynes et al. (1999), α = .86 **Professional compromise** 4 items questionnaire by Haynes et al. (1999), α = .75 **Role conflict** 4 items questionnaire by Haynes et al. (1999), α = .74 **Role clarity** 5 items questionnaire by Haynes et al. (1999), α = .71 **Feedback** 4 items questionnaire by Haynes et al. (1999), α = .81

1	A, C, E	**Job demands**	
		Development	
		OR = 1.38	**-**
		(CI 1.11 - 1.71)	
		Maintenance	
		OR = 1.27	**-**
		(CI 1.02 - 1.58)	
		Autonomy and control	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Influence over decisions	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = 1.30	**+**
		(CI 1.05 - 1.62)	
		Peer support	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Leader support	
		Development	
		OR = .69	**+**
		(CI .51 - .94)	
		Maintenance	
		OR = n.r.	**0**
		Professional compromise	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Role conflict	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Role clarity	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Feedback	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**

#Jansson-Frojmark et al., 2007 IP, 1 TL: 1 year	1873 mixed occupation (age: 50 - 60), Sweden, rr T1: n.r. rr T2: n.r.	4 items from BNSQ_ (Partinen & Gislason, 1995) and USI (Liljenberg et al., 1988), α not indicated	**Job demands** 6 items questionnaire by Haynes et al. (1999), α not indicated **Autonomy and control** 6 items questionnaire by Haynes et al. (1999), α not indicated **Influence over decisions** 4 items questionnaire by Haynes et al. (1999), α not indicated **Peer support** 4 items questionnaire by Haynes et al. (1999), α not indicated **Leader support** 6 items questionnaire by Haynes et al. (1999), α not indicated **Professional compromise** 4 items questionnaire by Haynes et al. (1999), α not indicated **Role conflict** 4 items questionnaire by Haynes et al. (1999), α not indicated **Role clarity** 5 items questionnaire by Haynes et al. (1999), α not indicated **Feedback** 4 items questionnaire by Haynes et al. (1999), α not indicated

1	A, C, E	**Job demands**	
		Development	
		OR = 1.28	**-**
		(CI 1.05 - 1.55)	
		Maintenance	
		OR = 1.24	**-**
		(CI 1.03 - 1.50)	
		Autonomy and control	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Influence over decisions	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = 1.38	**+**
		(CI 1.16 - 1.63)	
		Peer support	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Leader support	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Professional compromise	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = 1.21	**-**
		(CI 1.01 - 1.47)	
		Role conflict	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Role clarity	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**
		Feedback	
		Development	
		OR = n.r.	**0**
		Maintenance	
		OR = n.r.	**0**

Lallukka et al., 2011 IP, 1 TL: 5 - 7 years	6646 mixed occupation, predominantly female, Finland, rr T1: 67% rr T2: 83%	4 items JSQ (Jenkins et al., 1988), α = .84	**Being bullied at work** 1 item from Lehto (1991) **Observed bullying at work** 1 item from Lehto (1991)
Linton, 2004 IP, 1 TL: 1 year	816 mixed occupation, Sweden, rr T1: n.r. rr T2: 79%	Items from BNSQ_ (Partinen & Gislason, 1995) and USI (Liljenberg et al., 1988), α not indicated	**Job demands** Questionnaire by Hane et al. (1984), α not indicated **Job content (decision latitude)** Questionnaire by Hane et al. (1984), α not indicated **Social support** Questionnaire by Hane et al. (1984), α not indicated

1	A, C, D, E	**Being bullied at work**	
		Men	
		OR = 1.81	**0**
		(CI .94 - 3.48)	
		Women	
		OR = .99	**0**
		(CI .74 - 1.33)	
		Observed bullying at work	
		Men	
		OR = 1.05	**0**
		(CI .57 - 1.94)	
		Women	
		OR = 1.23	**0**
		(CI .96 - 1.56)	
1	A, C, D, E	**Job demands**	
		OR = 1.42	**0**
		(CI .93 - 2.17)	
		Job content (decision latitude)	
		OR = 1.49	**0**
		(CI .96 - 2.33)	
		Social support	
		OR = 1.64	**+**
		(CI 1.06 - 2.54)	

Magnusson Hanson et al., 2011 FP, 1 TL: 2 years	3041 mixed occupation, Sweden, rr T1: 65% rr T2: 78%	7 items KSQ (Kecklund & Åkerstedt, 1992), α = .80 - .85	**Job demands** 5 items DCQ (Theorell, 1988), α = .72 - .75 **Decision authority** 2 items DCQ (Theorell, 1988), α = .73 - .77 **Social support** 6 items DCQ (Theorell, 1988), α = .85

2	A, B, C, D, E, F	**Job demands**	
		Sleep disturbances	
		SEM model	
		χ^2 (NC) = 1255.33	
		β (NC) = .03	**0**
		β (RC) = .01	**0**
		Awakening problems	
		SEM model	
		χ^2 (ReC) = 1137.92	
		β (NC) = .02	**0**
		β (RC) = .03	**0**
		Decision authority	
		Sleep disturbances	
		SEM model	
		χ^2 (NoC) = n.s.	
		β (NC) = -.01	**0**
		β (RC) = -.02	**0**
		Awakening problems	
		SEM model	
		χ^2 (ReC) = 255.47	
		β (NC) = -.04	**+**
		β (RC) = -.04	**+**
		Social support	
		Sleep disturbances	
		SEM model	
		χ^2 (RC) = 1285.46	
		β (NC) = -.03	**0**
		β (RC) = -.08	**+**
		Awakening problems	
		SEM model	
		χ^2 (ReC) = 1123.33	
		β (NC) = -.04	**+**
		β (RC) = -.06	**+**

Ota et al., 2009 IP, 1 TL: 2 years	1022 employees at an electrical products corporation (age: ≤ 39 years), predominantly male, Japan, rr T1: 92% rr T2: n.r.	4 self-constructed items, α not indicated	**Job strain (job demands/job control)** *Job demands* 5 items JCQ (Karasek, 1985), α = .80 *Job control* 9 items JCQ (Karasek, 1985) α = .67 **Social support** 8 items JCQ (Karasek, 1985),α = .83 **Effort-reward imbalance** *Effort* 6 items ERI-Q (Siegrist & Peter, 1996), α = .83 *Reward* 11 items ERI-Q (Siegrist & Peter, 1996), α = .86 **Overcommitment** 6 items ERI-Q (Siegrist & Peter, 1996), α = .76
Ribet & Derriennic, 1999 IP, 1 TL: 5 years	18695 mixed occupation (age: only birth years 1938, 1943, 1948, and 1953), France, rr T1: 88% rr T2: 87%	5 items NHP (Martini & McDowell, 1975), α not indicated	**Job demands (Having to hurry)** 1 self-constructed item **Job control** 1 self-constructed item **Doing several things at the same time** 1 self-constructed item **Opportunity for learning** 1 self-constructed item **Job diversity** 1 self-constructed item **Interruptions** 1 self-constructed item
Rugulies et al., 2009 IP, 1 TL: 5 years	2351 mixed occupation, Denmark, rr T1: 75% rr T2: 69%	2 self-constructed items	**Effort-reward imbalance** *Effort* 4 proxy items of ERI-Q, α = 0.63 *Reward* 7 proxy items of ERI-Q, α = 0.53

1	A, B, C, D, E	**Job strain (job demands/job control)**	
		Development	
		OR = 1.72	-
		(CI 1.06 - 2.79)	
		Maintenance	
		OR = 1.32 (CI .75 - 2.34)	0
		Social support	
		Development	
		OR = .95	0
		(CI .63 - 1.45)	
		Maintenance	
		OR = 2.00	+
		(CI 1.18 - 3.40)	
		Effort-reward imbalance	
		Development	
		OR = 1.38 (CI .65 - 2.94)	0
		Maintenance	
		OR = 2.40	-
		(CI 1.13 - 5.10)	
		Overcommitment	
		Development	
		OR = 1.75	-
		(CI 1.16 - 2.66)	
		Maintenance	
		OR = 1.39 (CI .83 - 2.34)	0
1	A, D, G	**Job demands**	
		(Having to hurry)	
		OR = 1.50	-
		(CI 1.30 - 1.60)	
		Job control	
		OR = 1.40	+
		(CI 1.20 - 1.50)	
		Doing several things at the same time	
		OR = 1.10	0
		(CI 1.00 - 1.30)	
		Opportunity for learning	
		OR = 1.30	+
		(CI 1.20 - 1.40)	
		Job diversity	
		OR = 1.40	+
		(1.20 - 1.50)	
		Interruptions	
		OR = 1.00	0
		(CI .9 - 1.10)	
1	A, B, C, D, E, G	Men	
		OR = 2.06	-
		(CI 1.14 - 3.74)	
		Women	
		OR = .98	0
		(CI .59 - 1.63)	

Virtanen et al., 2011 FP, 1 TL: 12 years	1013 mixed occupation (approximately same age and from same area), Sweden, rr T1: n.r. rr T2: 94%	1 self-constructed item	**Job insecurity** 1 self-constructed item

Note: Ref. = reference, # = participants from same cohort, FP = full-panel design, IP = incomplete panel design, TL = time lag, rr = response rate, n.r. = insignificant results not reported, NC = normal causation, NoC = no causation, RC = reversed causation, ReC = reciprocal causation, BNSQ = Basic Nordic Sleep Questionnaire, CES-D = Center for Epidemiologic Studies Depression Scale, DCQ = Demand Control Questionnaire, ERI-Q = Effort-Reward Imbalance Questionnaire, JCQ = Job Content Questionnaire, JSQ = Jenkins Sleep Questionnaire, KSQ = Karolinska Sleep Questionnaire, NHP = Nottingham Health Profile, QPSNordic = General Nordic Questionnaire for Psychological and Social factors at Work, USI = Uppsala Sleep Inventory, 1 = logistic regression, 2 = Structural Equation Modelling, 3 = linear regression, 4 = ANOVA/ANCOVA, 5 = oneway analysis of variance and multiple range tests using LSD procedure, A = demographic information, B = lifestyle factors, C = work factors, D = health variables, E = T1 dependent variables, F = potential change of independent variables, G = other factors, + = positive association, - = negative association, 0 = no association

1	A, E	Moderate job insecurity, no temporary employment OR = 1.43 (CI 1.01 - 2.05)	-
		Heavy job insecurity, no temporary employment OR = 2.93 (CI 1.60 - 5.35)	-
		Moderate job insecurity, moderate temporary employment OR = 1.13 (CI .64 - 2.03)	0
		Heavy job insecurity, moderate temporary employment OR = 1.68 (CI .74 - 3.83)	0
		Moderate job insecurity, heavy temporary employment OR = 1.04 (CI .60 - 1.82)	0
		Heavy job insecurity, heavy temporary employment OR = 1.61 (CI .79 - 3.28)	0

Table 3 Detailed information on intervention studies.

Reference	Sample	Measurement of variables	
		Sleep	*Work characteristics*
Bourbonnais et al., 2006 + 2011 1 control group, no randomization, 2 TL: 1 and 3 years, pre + 2 x post	247 (experimental) and 220 (control) care providers, predominantly female, Canada, rr T1 Exp = 73% rr T1 Con = 69% rr T2 Exp = 45% rr T2 Con = 35% rr T3 Exp = 65% rr T3 Con = 56% Intervention designed to enhance job demands, job control, social support, and effort-reward imbalance by means of an intervention team which proposes solutions to enhance these work characteristics	5 items NHP (Martini & McDowell, 1975), α = .78	**Job demands** 9 items JCQ (Karasek, 1985), α = .76 **Job control** 9 items JCQ (Karasek, 1985), α = .71 **Social support** 8 items JCQ (Karasek, 1985), α = .81 **Reward** 11 items ERI-Q (Siegrist & Peter, 1996), α = .77 **Effort-reward imbalance** Effort constructed with JCQ
Moen et al., 2011 1 control group, no randomization, 1 TL: 6 months, pre + post	325 (experimental) and 334 (control) white collar employees, US, rr T1: 80% rr T2: 92% Intervention designed to enhance job (schedule) control by means of a participatory training of work teams to promote adjustment of work processes to enhance job control	1 item from Burgard and Ailshire (2009)	**Schedule control** 1 modified item (Thomas & Ganster, 1995)

Statistical analysis		Outcome	Association
Analysis reported	*Confounders*		
4	C, D, E, F	Sleep quality T2 p = .21	**0**
		Sleep quality T3 p = .17	**0**
2	A, C, E, F	Sleep quality β = .012	**0**

Wahlstedt & Edling, 1997 no control group, no randomization, 2 TL: 8 and 12 months, pre + 2 x post	100 postal sorting terminal employees, Sweden, rr T1: 93% rr T2: 79% Intervention designed to enhance job demands, decision latitude, and social support by means of organizational changes in working conditions	10 items sleep quality index by Theorell (1988), α not indicated	**Job demands** 5 items from questionnaire by Theorell (1988), α = .78 **Skill discretion** 4 items from questionnaire by Theorell (1988), α = .68 **Decision authority** 2 items from questionnaire by Theorell (1988), α = .78 **Contact with superiors** 5 items from questionnaire by Theorell (1988), α = .77 **Contact with teammates** 4 items from questionnaire by Theorell (1988), α = .69 **Social support** 16 items from questionnaire by Theorell (1988), α = .79

Note: Ref. = reference, TL = time lag, rr = response rate, n.s. = non-significant, JCQ = Job Content Questionnaire, NHP = Nottingham Health Profile, 1 = logistic regression, 2 = Structural Equation Modelling, 3 = linear regression, 4 = ANCOVA, if significant interaction general estimating equations, 5 = oneway analysis of variance and multiple range tests using LSD procedure, A = demographic information, B = lifestyle factors, C = work factors, D = health variables, E = T1 dependent variables, F = potential change of independent variables, G = other factors, + = positive association, - = negative association, 0 = no association

5	A, B, E, F	T2	
		Job demands	
		no change, no significant interaction	
		p = n.r.	**0**
		Skill discretion no change, no significant interaction	
		p = n.r.	**0**
		Decision authority	
		no change, no significant interaction	
		p = n.r.	**0**
		Contact with superiors	
		significant change, no significant interaction	
		p = n.r.	**0**
		Contact with team mates	
		no change, but significant interaction, group with less contact, poorer sleep quality	
		p = n.r.	**0**
		T3	
		Job demands	
		no change, no significant interaction	
		p = n.r.	**0**
		Skill discretion	
		significant change, significant interaction, group with less contact, poorer sleep quality	
		p < .05	**+**
		Decision authority	
		significant change, no significant interaction	
		p = n.r.	**0**
		Contact with superiors	
		no change, but significant interaction, group with less contact, poorer sleep quality	
		p < .01	**0**
		Contact with teammates	
		no change, but significant interaction, group with less contact, poorer sleep quality	
		p < .01	**0**

APPENDIX B: SUPPLEMENTARY MATERIAL OF CHAPTER 4

Table 1 Means, standard deviations and correlations between research variables

		M	*SD*	1	2	3	4	5
1	**Gender**[a]	1.59	0.49					
2	**Age**	49.05	8.58	-.01				
3	**Educational level (1-5)**	3.28	1.36	.13**	-.14**			
4	**Work schedule T1**[b]	0.09	0.28	.09**	.00	-.15**		
5	**Decision authority T1 (1-4)**	3.10	0.74	-.09**	.06**	.14**	-.18**	
6	**Job demands T1 (1-4)**	2.59	0.53	.09**	-.01	.12**	.04*	-.17**
7	**Job demands T2 (1-4)**	2.60	0.52	.08**	-.04*	.08**	.04*	-.13**
8	**Job demands T3 (1-4)**	2.59	0.55	.09**	-.09**	.07*	.05**	-.14**
9	**Sleep disturbances T1 (1-6)**	2.64	1.07	.13**	.08**	.03	.04	-.12**
10	**Sleep disturbances T2 (1-6)**	2.62	1.05	.11**	.11**	.01	.05**	-.08**
11	**Sleep disturbances T3 (1-6)**	2.64	1.05	.14**	.10**	.01	.06**	-.11**
12	**Awakening problems T1 (1-6)**	2.67	1.08	.11**	-.17**	.06**	-.01	-.12**
13	**Awakening problems T2 (1-6)**	2.59	1.07	.08**	-.15**	.07**	.00	-.10**
14	**Awakening problems T3 (1-6)**	2.57	1.06	.15**	-.14**	.07**	.00	-.12**
15	**Perseverative cognition T1 (1-4)**	2.23	0.80	.02	.02	.16**	-.07**	.00
16	**Perseverative cognition T2 (1-4)**	2.27	0.82	-.01	-.04*	.14**	-.06**	.04*
17	**Perseverative cognition T3 (1-4)**	2.24	0.82	.03	-.04*	.13**	-.05**	.02

Note: [a] 1 = male, 2 = female, 52% ; b 0 = no shift work, 1= shift work, 8.5% shift work
* = $p < 0.05$, ** = $p < 0.01$ (two-tailed), n = 3017-308

	6	7	8	9	10	11	12	13	14	15	16
	.60**										
	.55**	.60**									
	.29**	.24**	.22**								
	.24**	.28**	.24**	.72**							
	.23**	.23**	.27**	.66**	.71**						
	.25**	.21**	.20**	.46**	.33**	.32**					
	.21**	.24**	.21**	.35**	.45**	.36**	.68**				
	.21**	.22**	.26**	.38**	.39**	.52**	.67**	.72**			
	.44**	.34**	.29**	.44**	.35**	.32**	.28**	.23**	.22**		
	.34**	.43**	.33**	.34**	.41**	.32**	.24**	.28**	.23**	.64**	
	.31**	.34**	.42**	.34**	.35**	.41**	.25**	.25**	.29**	.61**	.67**

APPENDIX C: SUPPLEMENTARY MATERIAL OF CHAPTER 7

Table 1 Evaluation criteria for longitudinal studies

Criteria	0 stars (insufficient)	** 2 stars (sufficient)	*** 3 stars (good)
1. Applied design	Incomplete panel design (2 TP, ≥ 1 central research variables measured only at 1 TP)	Incomplete panel design (> 2 TP, ≥ 1 central research variables measured more than once but not on all TP)	Complete panel design (All variables measured at each TP)
2. Measures: Sleep quality	- Unclearly formulated global one-item sleep quality measure, *or* - Clearly formulated global one-item sleep quality measure, but only 2 response categories, *or* - Facet sleep quality measure assessing only 1 out of 4 sleep quality aspects	- Clearly formulated global one-item sleep quality measure with clear response categories (> 2), *or* - Clearly formulated facet sleep quality measure assessing 2 out of 4 sleep quality aspects	Clearly formulated facet sleep quality measure assessing at least 3 out of 4 sleep quality aspects
3. Measures: Work characteristics	No work characteristics measured validly (i.e., no correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	Some, but not all, work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	All work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)
4. Non-response analysis	No check on selectivity of the sample	Check on selectivity of the sample either at baseline *or* follow-up	Check on selectivity of the sample at both baseline *and* follow-up
5. Statistical adjustment	**Either** no adjustment for: - Potential confounders, *and* - T1 dependent variables, *and* - Potential change of independent variables **OR** adjustment for potential confounders, but no adjustment for: - T1 dependent variables, *and* - Potential change of independent variables	Adjustment for potential confounders, **AND** adjustment for: - T1 dependent variables, *or* - Potential change of some independent variables	Adjustment for potential confounders, **AND** adjustment for: - T1 dependent variables, *and* - Potential change of independent variables

Note: TP = time point(s), JCQ = Job Content Questionnaire, ERI = Effort-Reward Imbalance Questionnaire, VBBA = Dutch Questionnaire on the Experience and Evaluation of Work, COPSOQ = Copenhagen Psychosocial Questionnaire

Table 2 Evaluation criteria for intervention studies

Criteria	0 stars (insufficient)	** 2 stars (sufficient)	*** 3 stars (good)
1. Control group and randomization	No control group or randomization	One control group, but no randomization	At least one control group and randomization
2. Measuring TPs: Sleep quality	Pre *or* post intervention only	Pre *and* post intervention	At least 1 pre *and* > 1 post intervention
3. Measuring TPs: Work characteristics	Pre *or* post intervention only	Pre *and* post intervention	At least 1 pre *and* > 1 post intervention
4. Intervention content	The initial problem (regarding psychosocial work characteristics and/or sleep quality) is not clear and/or intervention does not fit initial problem		The initial problem (regarding psychosocial work characteristics and/or sleep quality) is clear and intervention fits initial problem
5. Intervention process	No information about the implementation process is presented		Information about the implementation process is presented
6. Measures: Sleep quality	- Unclearly formulated global one-item sleep quality measure, *or* - Clearly formulated global one-item sleep quality measure, but only 2 response categories, *or* - Facet sleep quality measure assessing only 1 out of 4 sleep quality aspects	- Clearly formulated global one-item sleep quality measure with clear response categories (> 2), *or* - Clearly formulated facet sleep quality measure assessing 2 out of 4 sleep quality aspects	Clearly formulated facet sleep quality measure assessing at least 3 out of 4 sleep quality aspects
7. Measures: Work characteristics	No work characteristics measured validly (i.e., no correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	Some, but not all, work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)	All work characteristics measured validly (i.e., correct use of validated scales such as JCQ, ERI, VBBA, COPSOQ)
8. Non-response analysis	No check on selectivity of the sample	Check on selectivity of the sample either at baseline *or* follow-up	Check on selectivity of the sample at both baseline *and* follow-up
9. Statistical adjustment	**Either** no adjustment for: - Potential confounders, *and* - T1 dependent variables **OR** adjustment for potential confounders, but no adjustment for T1 dependent variables		Adjustment for potential confounders, **AND** adjustment for T1 dependent variables

Note: TP = time point(s), JCQ = Job Content Questionnaire, ERI = Effort-Reward Imbalance Questionnaire, VBBA = Dutch Questionnaire on the Experience and Evaluation of Work, COPSOQ = Copenhagen Psychosocial Questionnaire

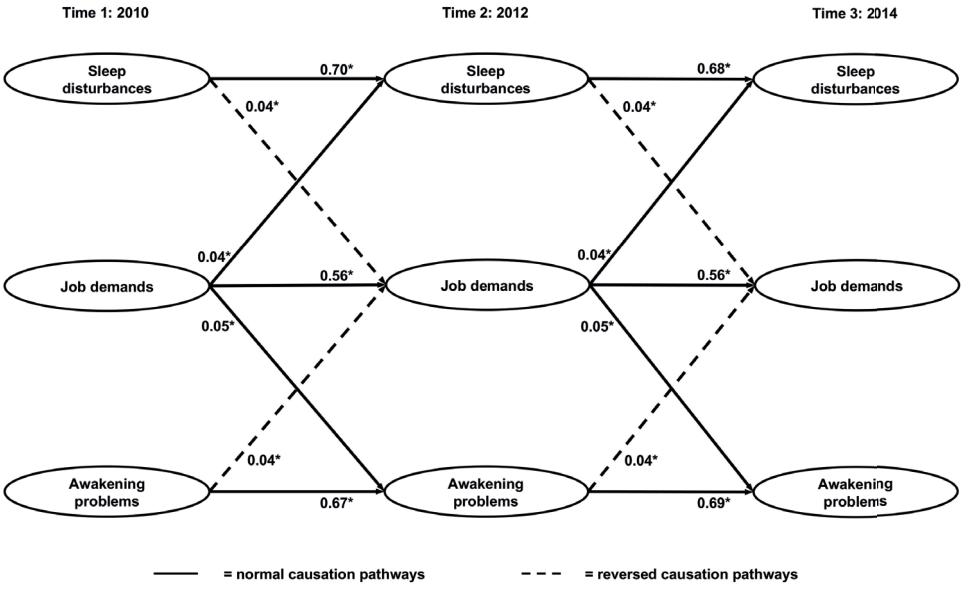

Figure 1 Overview of the normal and reversed pathways and standardized regression coefficients (β). The model is adjusted for age, gender, educational level, work schedule, and decision authority, but for clarity these pathways are not depicted

Note: * = $p < 0.05$

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English Summary

INTRODUCTION

Occupational health research has consistently shown that highly demanding work is a major source of work stress. Work under stressful conditions requires cognitive, emotional, and/or physical effort that is associated with psycho-physiological load effects. According to Effort-Recovery theory (Meijman & Mulder, 1998), recovery during or after work is crucial to reduce load effects and to let psycho-physiological systems return to baseline levels. When recovery is incomplete while facing new challenges, compensatory effort is needed, thereby further increasing the demands on the recovery process. As a result, psycho-physiological load effects may accumulate. Following Allostatic Load theory (McEwen, 1998), a chronic imbalance between effort and recovery will result in an adverse bodily state called 'allostatic load', which has negative consequences for health. Although the links between demanding work, stress, and adverse health have been studied, little is known about the actual day-to-day and week-to-week time course of stress and recovery in face of a stressful event. Understanding this time course may contribute to our understanding of the interplay between stress, recovery, and health.

In light of the prominent role of sufficient recovery in upholding health, it is important to focus on sleep as a key recovery opportunity. Whereas sleep promotes psychophysiological recovery from stress and is vital in averting ill-health, stress may actually impede good sleep. There are indications that stress-related cognitive processes (e.g., worrying, rumination) are key factors in stress-related sleeping difficulties. In scientific literature, such a negative thought process is often coined perseverative cognition (PC), i.e., a mental preoccupation with past or future stressors.

To date, only few researchers have examined the relations between stress, PC, and sleep. The scarce previous studies point towards a negative relation between work stress and sleep. However, longitudinal designs with a focus on the temporal characteristics of the work stress–sleep relationship are very scarce, hence, the temporal relation between stress, PC, and sleep is not well understood. The core assumption of the stressor creation hypothesis (Bowling & Jex, 2013; Spector et al., 2000) is that next to the traditional causal relation (e.g., stress has an influence on subsequent sleep), a reversed causal relation is plausible as well (i.e., poor sleep leading to an increase in actual or perceived stressors). Another shortcoming of previous research is that PC has been often overlooked as a promising underlying mechanism in the proposed work stress-sleep relationship, and thus, the exact role of PC in this relationship is still unclear. Attempting to fill these gaps in knowledge, the main objectives of this dissertation were to examine (i) the

temporal relations between work-related stress(ors), PC, and sleep, (ii) the role of PC as a potential underlying mechanism in the stress-sleep relationship, and (iii) the development of stress and sleep over time.

RESULTS OF ALL STUDIES

In **chapter 2**, a systematic review of the scientific literature about the reciprocal associations between psychosocial work stressors and sleep quality showed evidence for a negative relation between job demands and subsequent sleep quality, and for a positive relation between job control and subsequent sleep quality. However, a quality assessment of previous scientific research also showed that (high-quality) research into the temporal associations between work stressors and sleep quality is scarce. Moreover, most previous research did not examine reciprocity between stressors and sleep nor paid attention to PC as potential underlying mechanism linking stress(ors) to sleep. Addressing these limitations, we performed two long-term longitudinal studies.

In chapters 3 and 4, two large scale full-panel longitudinal studies were presented to unravel temporal relations between work stress(ors), work-related PC, and sleep quality, with special attention for mutual influences over time. Moreover, it was examined whether work-related PC is an underlying mechanism in the stress(or)-sleep relationship. In **chapter 3**, a two-wave full-panel study among a large, heterogeneous sample of the Dutch working population showed that work-related stress and work-related PC were positively and reciprocally related over time. Work-related PC and sleep quality were negatively and reciprocally related. Work-related PC was found to fully mediate the prospective negative relationship between work-related stress and subsequent sleep quality. In **chapter 4**, a three-wave full-panel study confirmed the reciprocal relations found in chapter 3 and extended these results to job demands (as compared to work-related stress). Work-related PC served as a mediator in both the normal and reversed relations between job demands on the one hand and sleep disturbances and awakening problems on the other. Moreover, employees reporting continuous high job demands across all waves reported higher sleep disturbances, awakening problems, and more work-related PC compared to employees with stable moderate- or stable low job demands.

The first three studies focused on long-term processes. In chapters 5 and 6, short-term (i.e., day-level) processes were emphasized. These chapters represent two articles, each based on a longitudinal diary-based study, in which we followed PhD students awaiting and following a stressful life event (i.e., their public

dissertation defence). In **chapter 5**, the focus was on the development of stress, fatigue, and sleep quality leading up to and following that stressful life event. Stress levels increased leading up to the defence and decreased rapidly following the defence. Fatigue remained unchanged leading up to the defence, but did increase immediately following the defence, before slowly decreasing thereafter. Sleep quality did not decrease leading up to the defence, but improved directly following the defence. One month before the defence, stress levels were already elevated compared to one month post defence. Day-level stress was adversely affected by day-level negative anticipation and favourably by day-level positive outcome expectancy regarding the defence. Positive outcome expectancy was an important predictor of sleep quality on the day-level. In **chapter 6** we took advantage of the natural within-person variation created by the stressful life event and examined day-level relations between stress, PC, and objective and subjective sleep parameters. Day-level stress was associated with day-level PC, which, in turn, was related to several day-level objective sleep parameters (i.e., sleep efficiency, marginally to number of awakenings and wake after sleep onset), and to several day-level subjective sleep parameters (i.e., sleep quality, number of awakenings and wake after sleep onset). Day-level PC functioned as a mediator in between day-level stress and day-level sleep quality (i.e., subjective sleep quality, objective sleep efficiency, and subjective wake after sleep onset).

DISCUSSION

Temporal relations between work-related stress(ors), perseverative cognition, and sleep

The studies examined in the systematic review (chapter 2) found evidence for temporal relations in the traditional direction from job demands and job control to sleep quality. The review revealed that reversed and reciprocal across-time relations between sleep and stress(ors) were largely neglected in previous studies. Moreover, hardly any previous research examined the role of PC in the relation between stress and sleep. In both long term longitudinal studies (chapters 3 and 4), we found reciprocal adverse relations between work stress(ors) and PC, and between PC and sleep quality. Additionally, chapter 6 focused on day-level associations between work stress and PC, as well as between PC and sleep quality (normal causation paths only), and indeed found temporal day-level relations between these concepts. In all studies, the direct relation between work stress(ors) and sleep was ambiguous when concurrently examining work-related PC, hinting toward an important mediating role of PC in the stress-sleep relationship.

Perseverative cognition as an underlying mechanism of the stress-sleep relationship

Both long term longitudinal studies (chapters 3 and 4) as well as the diary study (chapter 6) of this dissertation found that PC was a mediating mechanism in the prospective pathway from stress(or) to sleep quality. Our findings support the perseverative cognition hypothesis (Brosschot et al., 2006), which states that continuous mental representation of stressors may cause prolonged physiological activation, and consequently poor sleep quality, rather than (or in addition to) the stressors themselves. The results of the longitudinal diary-based study extend the perseverative cognition hypothesis to the day-level. Moreover, chapter 4 showed that the mediating role of PC seems to apply to both sleep disturbances (i.e., lack of sleep continuity) and awakening problems (i.e., being insufficiently restored at awakening) and chapter 6 showed that the mediating role of PC was found not only for subjective measures of sleep disturbances but also extends to objective measures of sleep quality (i.e., objective measures of sleep efficiency). Besides the normal causal path from stress(ors) to sleep, in chapter 4, we also found that PC mediates the reverse relation between sleep quality and stressors. This finding is in line with the stressor creation hypothesis (Bowling & Jex, 2013; Spector et al., 2000), which suggests that poor sleep results in a (perceived) adverse change in the work environment. We can conclude that PC indeed seems to be an important underlying mechanism in the short term as well as long term reciprocal negative relationship between stress(ors) and sleep.

Development of stress and sleep over time

In chapters 4 and 5, we were able to shed some light on the time course of stress and sleep in both the long- and the short term. Employees exposed to continuous high job demands over a period of four years experienced lower sleep quality (i.e., more sleep disturbances and awakening problems) and higher work-related PC than employees with continuous moderate and low job demands. In the short term, our diary-based study showed that PhD students awaiting a stressful life event (i.e. their PhD defence) already reported elevated stress four weeks before the stressful event took place. In the weeks leading up to the stressful event, stress increased even more, however, afterwards stress levels quickly dropped. Sleep quality was rather high and remained more stable leading up to and during the four weeks following the stressful event and only increased slightly directly following the stressful event, indicating adequate recovery throughout the period in which respondents were anticipating the stressful event. The results regarding the long-term and short-term development of stress, PC and sleep are mostly in line with Effort-Recovery theory (Meijman & Mulder, 1998) and Allostatic Load

theory (McEwen, 1998), which provide a theoretical understanding of the development of stress and sleep problems. The studies performed in this dissertation provide a partial answer to the question how stress and sleep develop over time. If one is stressed by work or other important, stressful events for a prolonged period (from months to several years), stress levels are heightened but seem to stabilize at some point. At the same time, PC and sleep complaints remain stable as well. Only after the stressor has diminished or disappeared, stress levels and sleep quality improve again.

STRENGTHS AND LIMITATIONS

Important strengths of the research presented in this dissertation are the use of high-quality research designs such as full-panel longitudinal studies and longitudinal diary-based designs, the use of subjective and objective methods to assess sleep, and the use of different time lags from long-term, longitudinal studies with time lags of one to several years, to short-term diary-based studies with daily or weekly measures. The high-quality research designs enabled us to examine reciprocal temporal, short-term as well as long-term, relations between stress(ors), PC, and sleep quality, and permitted cautious conclusions about causal order.

Another important strength is the contribution to and extension of important theories within the stress and recovery literature. In this dissertation, we not only found 'normal', but also 'reversed' temporal relations between work stress, PC, and sleep, providing evidence for the stressor creation hypothesis (Bowling & Jex, 2013; Spector et al., 2000). Additionally, supporting the PC-hypothesis (Brosschot et al., 2006), we revealed that PC is an underlying mechanism in the reciprocal relation between work stress and sleep. Moreover, with our diary study, we were able to extend the PC hypothesis to the day-level. Lastly, the studies in this dissertation provided more insight into the long- and short term time course of stress and sleep.

Nonetheless, the studies in this dissertation have some limitations, which should be addressed in future research. We mainly used self-report measures to examine work-related stress, PC, and sleep (with the notable exception of chapter 6, that included objective measures of sleep), of which some were single item measures. Another limitation concerns the assessment of PC the longitudinal diary-based study. Although the single multiple-response item provided detailed and relevant information about the content of PC, it lacked an optimal assessment of the duration or intensity of PC. A related issue concerns the conclusion that can be drawn from the mediation analysis in the longitudinal diary-based study. As

the PC item assessed participants' PC during bedtime and/or the night, we could not disentangle whether PC in the evening led to more sleep disturbances during the night, or whether, alternatively, sleep disturbances facilitated PC during nightly awakenings.

PRACTICAL IMPLICATIONS

From a valorisation perspective, whenever possible, work-directed prevention of stress should be the first step. As such, the importance of well-designed and healthy jobs (i.e., jobs characterized by challenging [but not too high] job demands, sufficient job autonomy, job support and job variety, and a proper work-rest schedule) as a means to prevent work stress needs to be emphasized. Additionally, organizations are advised to also provide resources to help their employees cope with stress and PC, such as increasing employee-oriented work(time) flexibility and/or promoting recovery after work and psychological detachment from work (e.g., by providing gym memberships to facilitate exercise, psychological services, training in stress-management techniques and/or sleep hygiene). As a last resort, employees suffering from (chronic) stress may benefit from worker-directed interventions targeted at reducing stress-related health problems (e.g., exercise training for employees showing early signs of burnout).

The following implications are in response to our findings regarding reciprocity of the stress-PC-sleep relations and PC as an underlying mechanism of the stress-sleep relationship. Employees and employers should be informed that high stress is not only related to reduced sleep quality, but that poor sleep quality is also related to an increase in actual or perceived stress. Knowing that the stress-sleep relation is a two-way street should raise awareness for the possibility that sleep complaints may also be a point of attack for dealing with problematic stress (e.g., by means of improving sleep hygiene). Moreover, employees should attempt to reduce PC and associated stress and sleep complaints by seeking distraction and by undertaking activities that stimulate post-work unwinding, for example through regular exercise and engaging in (other) activities that induce positive affect.

CONCLUSION

The studies presented in this dissertation rendered insight into the temporal interrelations between work-related stress(ors), PC, and sleep, providing evidence for

adverse reciprocal relations between these concepts. Importantly, this dissertation has shown that PC is a key underlying mechanism in the reciprocal stress-sleep relationship.

Nederlandse Samenvatting

INLEIDING

Onderzoek binnen de arbeids- en gezondheidspsychologie heeft aangetoond dat veeleisend werk een belangrijke bron van werkstress is. Werken onder stressvolle omstandigheden vereist cognitieve, emotionele en/of fysieke inspanning, hetgeen samengaat met psychofysiologische belasting. Volgens de '*Effort-Recovery*' theorie (Meijman & Mulder, 1998) is voldoende herstel tijdens of na het werk van cruciaal belang om de belastingseffecten te verminderen en psychofysiologische systemen terug te laten keren naar het basisniveau. Wanneer men al geconfronteerd wordt met nieuwe uitdagingen terwijl het herstel nog onvolledig is, is compensatoire inspanning nodig, hetgeen de eisen aan het herstelproces nog verder verhoogt. Hierdoor kunnen de psychofysiologische belastingseffecten accumuleren. Volgens de '*Allostatic Load*' theorie (McEwen, 1998) zal een chronische verstoring van de balans tussen inspanning en herstel leiden tot een negatieve lichamelijke toestand genaamd '*allostatic load*', met negatieve gevolgen voor de gezondheid. Hoewel de samenhang tussen veeleisend werk, stress en gezondheidsrisico's al eerder onderzocht is, is er weinig bekend over het (dag-tot-dag of week-tot-week) beloop van stress en herstel in aanloop naar een stressvolle gebeurtenis. Inzicht in dit beloop kan een bijdrage leveren aan ons begrip van de wisselwerking tussen stress, herstel en gezondheid.

Als we het hebben over het belang van herstel dan is een focus op slaap logisch, aangezien slaap gezien wordt als één van de belangrijkste herstelmogelijkheden. Slaap bevordert psychofysiologisch herstel van stress en is aldus van belang voor het behoud van een goede gezondheid. Stress is één van de kernfactoren die een goede nachtrust belemmeren. Er zijn aanwijzingen dat stress-gerelateerde cognitieve processen een belangrijke rol spelen in deze stress-gerelateerde slaapproblemen. In de wetenschappelijke literatuur wordt een dergelijk negatief gedachteproces vaak '*perseverative cognition*' genoemd, in het Nederlands gelijk aan 'piekeren'. Piekeren wordt gedefinieerd als een mentale preoccupatie met voorafgaande of toekomstige stressoren.

Tot dusver hebben slechts enkele onderzoekers de relaties tussen stress, piekeren en slaap onderzocht. Deze eerdere studies wijzen op een negatieve relatie tussen werkstress en slaap, maar longitudinale studies met een focus op de temporele relatie tussen werk, stress en slaap zijn schaars. Er is aldus maar beperkte empirische kennis over de temporele relatie tussen stress, piekeren en slaap. In theorie kan de veronderstelde causale relatie tussen stress(oren) en slaap reciproke zijn: Naast het traditionele pad (bijvoorbeeld dat inspanning en stress op het werk invloed heeft op slaap), veronderstelt de '*stressor creation*' hypothese (Bowling & Jex, 2013; Spector et al., 2000) een omgekeerde causale re-

latie waarbij slecht slapen zou leiden tot een toename van stressoren. Een andere tekortkoming van eerder onderzoek is dat piekeren vaak over het hoofd gezien wordt als een potentieel veelbelovend onderliggend mechanisme in de relatie tussen werkstress en slaap. Aldus is de exacte rol van piekeren in deze relatie is onduidelijk.

De belangrijkste doelstellingen van dit proefschrift waren (i) de temporele relaties tussen werkstress(oren), piekeren, en slaap te onderzoeken (ii) inzicht te krijgen in de rol van de piekeren als een potentieel onderliggend mechanisme in de stress-slaap relatie, en (iii) de ontwikkeling van stress en slaap over tijd te onderzoeken.

RESULTATEN VAN ALLE STUDIES

In hoofdstuk 2 wordt een systematische literatuurstudie gepresenteerd aangaande de empirische kennis over de causale verbanden tussen psychosociale werkkenmerken en slaapkwaliteit. Deze studie liet zien dat er vooral empirisch bewijs is voor een negatief verband tussen taakeisen en slaapkwaliteit en voor een positieve relatie tussen autonomie en slaapkwaliteit. Echter, een kwaliteitsbeoordeling van eerder wetenschappelijk onderzoek toonde ook aan dat onderzoek van hoge kwaliteit naar de temporele relaties tussen werk stressoren en slaapkwaliteit schaars is. Bovendien heeft het onderzoek tot op heden vrijwel geen aandacht besteed aan de mogelijke omgekeerde causale relatie tussen stressoren en slaap, en evenmin aan piekeren als potentieel onderliggend mechanisme. Met de twee grootschalige longitudinale studies uit dit proefschrift hebben we geprobeerd deze beperkingen van eerder onderzoek het hoofd te bieden.

In hoofdstuk 3 en 4 worden deze twee grootschalige, lange-termijn full-panel longitudinale studies gepresenteerd, welke inzicht geven in de temporele relaties tussen werkstress(oren), werkgerelateerd piekeren en slaapkwaliteit. Uit de full-panel studie in hoofdstuk 3 (twee meetmomenten binnen een grote, heterogene steekproef van de Nederlandse arbeidsbevolking) bleek dat er een positieve en reciproke temporele relatie bestaat tussen werkstress en werkgerelateerd piekeren. Tussen werkgerelateerd piekeren en slaapkwaliteit werd een negatieve, reciproke causale relatie gevonden. Werkgerelateerd piekeren bleek de negatieve relatie tussen werkstress en de daaropvolgende slaapkwaliteit volledig te mediëren. In de longitudinale studie van hoofdstuk 4 (3 meetmomenten) werden dezelfde reciproke relaties gevonden als in hoofdstuk 3 en werden de resultaten uitgebreid naar taakeisen (in plaats van werkstress). Werkgerelateerd piekeren bleek een onderliggend mechanisme (mediator) te zijn in zowel de normale als

in de omgekeerde relatie tussen taakeisen enerzijds en slaapverstoringen tijdens de nacht en problemen met wakker worden anderzijds. Bovendien rapporteerden werknemers met chronisch hoge taakeisen meer slaapverstoringen tijdens de nacht, meer problemen met wakker worden en meer werkgerelateerd piekeren over tijd, dan werknemers met stabiel matige of stabiel lage taakeisen.

De eerste drie studies waren gericht op lange termijn processen. In hoofdstuk 5 en 6 werden korte termijn (zoals dag-niveau) processen centraal gesteld aan de hand van een longitudinale dagboekstudie, waarin we promovendi volgden die toeleefden naar een stressvolle gebeurtenis: hun proefschriftverdediging. In hoofdstuk 5 lag de nadruk op de ontwikkeling (het beloop) van stress, vermoeidheid en slaapkwaliteit in aanloop naar en na afloop van de stressvolle gebeurtenis. Stressniveaus namen toe in aanloop naar de verdediging, maar vertoonden direct na de verdediging weer een scherpe afname. Vermoeidheid bleef onveranderd in aanloop naar de verdediging, verhoogde onmiddellijk na de verdediging, om vervolgens langzaam weer af te nemen. Slaapkwaliteit verslechterde niet in aanloop naar de verdediging, maar verbeterde wel onmiddellijk na de verdediging. Een maand voor de verdediging waren stressniveau al verhoogd ten opzichte van een maand na de verdediging. Stress werd ongunstig beïnvloed door negatieve anticipatie van de promotie op dag-niveau, en positief door een positieve verwachting van de uitkomst van de verdediging op dag-niveau. Een positieve verwachting van de uitkomst van de verdediging was een belangrijke voorspeller van slaapkwaliteit op dag-niveau.

In hoofdstuk 6 hebben we gebruik gemaakt van de natuurlijke binnen-persoons variatie in stress, piekeren en zowel objectieve als subjectieve slaap parameters, die in aanloop naar de stressvolle gebeurtenis (proefschriftverdediging) opgewekt werd. In dit hoofdstuk werden de dag-niveau relaties tussen stress, piekeren, en zowel objectieve als ook subjectieve slaap parameters onderzocht. Uit de statistische analyses bleek stress op dag-niveau gerelateerd te zijn aan piekeren, en piekeren was op zijn beurt gerelateerd aan verschillende objectieve slaapparameters (slaapefficiëntie, het aantal keren dat men wakker werd tijdens de nacht, en wakker worden nadat men voor de eerste keer in slaap is gevallen) en subjectieve slaapparameters (slaapkwaliteit, het aantal keren dat men wakker werd tijdens de nacht, en wakker worden nadat men voor de eerste keer in slaap is gevallen) op dag-niveau. Piekeren op dag-niveau bleek een onderliggend mechanisme (mediator) te zijn in de relatie tussen stress en slaapkwaliteit op dag-niveau (in de longitudinale dagboekstudie werd alleen het traditionele, causale pad onderzocht, d.w.z. van stress via piekeren naar slaap). Dit mediatie-effect werd gevonden voor subjectieve slaapkwaliteit, objectieve slaapefficiëntie, en de subjectieve meting van wakker worden nadat men voor de eerste keer in slaap is gevallen.

DISCUSSIE

Temporele relaties tussen werkstress(oren), piekeren en slaap

De systematische literatuurstudie (hoofdstuk 2) vond bewijs voor een temporele relatie in de traditionele richting van taakeisen en autonomie op het werk naar slaapkwaliteit. Onze evaluatie van eerder empirisch onderzoek wees uit dat de omgekeerde causale relatie tussen slaap en stress(oren) grotendeels genegeerd is. Bovendien werd de rol van piekeren in de relatie tussen stress en slaap nauwelijks onderzocht. In beide grootschalige longitudinale studies van dit proefschrift (hoofdstuk 3 en 4) vonden we bewijs voor reciproke ongunstige relaties tussen werkstress(oren) en piekeren en tussen de piekeren en slaapkwaliteit. Bovendien werden in hoofdstuk 6 temporele dag-level relaties gevonden tussen stress, piekeren en slaapkwaliteit. In alle studies uit dit proefschrift was de directe relatie tussen werkstress(oren) en slaap niet eenduidig of afwezig zodra werkgerelateerd piekeren werd opgenomen in het model. Deze bevindingen ondersteunen de veronderstelling dat piekeren een belangrijke mediërende rol speelt in de stress-slaap relatie.

Piekeren als onderliggend mechanisme van de stress-slaap relatie

Uit beide grootschalige lange-termijn longitudinale studies (hoofdstuk 3 en 4) en de dagboekstudie (hoofdstuk 6) van dit proefschrift blijkt dat piekeren een mediërend mechanisme was in de temporele relatie tussen stress(oren) en daaropvolgende slaapkwaliteit. Onze bevindingen ondersteunen de '*perseverative cognition*' hypothese (Brosschot et al., 2006) die veronderstelt dat een continue mentale representatie van stressoren in plaats van- of naast de stressoren zelf voldoende is om een langdurige fysiologische activatie te veroorzaken en te kunnen zorgen voor verstoorde slaapkwaliteit. De resultaten van de longitudinale dagboekstudie breiden de '*perseverative cognition*' hypothese uit en tonen aan dat deze ook toepasbaar is op dag-niveau. Bovendien bleek uit hoofdstuk 4 dat het mediatie-effect van piekeren zowel van toepassing is op slaapverstoringen tijdens de nacht (gebrek aan slaap continuïteit) als op problemen bij het wakker worden (men is onvoldoende hersteld na het wakker worden). Verder werd in hoofdstuk 6 gevonden dat de mediërende rol van piekeren niet alleen speelt bij de subjectieve ervaring van slaapproblemen maar ook aanwezig is in relatie tot objectieve metingen van slaapkwaliteit (objectieve slaapefficiëntie). Naast de traditionele causale relatie van stress(oren) tot opvolgende slaap, werd in hoofdstuk 4 gevonden dat piekeren ook de omgekeerde causale relatie tussen slaapkwaliteit en daaropvolgende ervaring van stressoren medieert. Deze bevinding is in lijn met

de '*stressor creation'* hypothese (Bowling & Jex, 2013; Spector et al, 2000) die suggereert dat slecht slapen kan leiden tot een negatieve (ervaren) verandering in de werkomgeving. We kunnen concluderen dat piekeren inderdaad een belangrijk onderliggend mechanisme blijkt te zijn op zowel de korte termijn als op lange termijn in de reciproke negatieve relatie tussen stress(oren) en slaap.

Het beloop van stress en slaap over tijd

In hoofdstuk 4 en 5 waren we in staat om het beloop van stress en slaap op zowel de lange als de korte termijn te onderzoeken. Werknemers die blootgesteld waren aan chronisch hoge taakeisen over een periode van vier jaar ervoeren een lagere slaapkwaliteit (meer slaapverstoringen tijdens de nacht en meer problemen met wakker worden) en hoger werkgerelateerd piekeren dan werknemers met continue matige en lage taakeisen. Op de korte termijn toonde onze longitudinale dagboekstudie aan dat promovendi in afwachting van een stressvolle gebeurtenis (hun proefschriftverdediging) reeds vier weken voor de stressvolle gebeurtenis verhoogde stress rapporteerden. In de weken voorafgaand aan de stressvolle gebeurtenis nam stress nog meer toe, maar daalde al snel na de gebeurtenis. Slaapkwaliteit was relatief hoog en bleef stabiel in aanloop naar- en in de vier weken na de stressvolle gebeurtenis, en steeg alleen licht direct na de stressvolle gebeurtenis. Deze bevinding laat zien dat respondenten adequaat herstelden gedurende de gehele periode waarin zij de stressvolle gebeurtenis anticipeerden. De resultaten met betrekking tot de lange termijn en korte-termijn ontwikkeling van stress, piekeren en slaap zijn grotendeels in lijn met de '*Effort-Recovery*' theorie (Meijman & Mulder, 1998) en de '*Allostatic Load*' theorie (McEwen, 1998) welke een theoretische onderbouwing bieden voor de ontwikkeling van stress en slaapproblemen. De studies die in dit proefschrift gepresenteerd worden, geven een gedeeltelijk antwoord op de vraag hoe stress en slaap ontwikkelen over tijd. Als men gedurende langere tijd (maanden tot jaren) gestrest is door werk of andere belangrijke, stressvolle gebeurtenissen zal stress aanvankelijk toenemen, maar die toename zal op een gegeven moment stabiliseren en niet meer verder toenemen. Tegelijkertijd blijven ook piekeren en slaapproblemen stabiel verhoogd. Pas nadat de stressor is afgenomen of verdwenen, verbeteren stress en slaapkwaliteit.

STERKTES EN ZWAKTES

Het onderzoek dat in dit proefschrift gepresenteerd wordt kent een aantal belangrijke sterke punten. Zo zijn de gebruikte designs van hoge kwaliteit, zoals bijvoorbeeld grootschalige, full-panel longitudinale studies en longitudinale

dagboekstudies. Ook werd slaap op zowel een subjectieve- als ook een objectieve manier gemeten en werden longitudinale studies met verschillende tijdsintervallen gebruikt. Zo ondernamen wij lange-termijn longitudinale studies met tijdsintervallen van één tot meerdere jaren maar ook korte-termijn longitudinale dagboekstudies met dagelijkse of wekelijkse tijdsintervallen. Deze onderzoeksdesigns van hoge kwaliteit stelden ons in staat om de reciproke temporele (zowel lange termijn als korte termijn) relaties tussen stress(oren), piekeren en slaapkwaliteit te onderzoeken en om voorzichtige conclusies over reciproke causaliteit te trekken.

Een ander belangrijk sterk punt is de bijdrage aan- en de uitbreiding van de belangrijkste theorieën binnen de wetenschappelijke stress(herstel) literatuur. In dit proefschrift hebben we niet alleen evidentie gevonden voor de 'normale', maar ook voor 'omgekeerde' temporele relaties tussen werkstress, piekeren en slaap, en is aldus bewijs geleverd voor de '*stressor creation*' hypothese (Bowling & Jex, 2013; Spector et al., 2000). Verder is eén van de kernbevindingen dat we hebben aangetoond dat piekeren een onderliggend mechanisme is in de reciproke relaties tussen werkstress en slaap. Deze bevinding bevestigd de '*perseverative cognition*' hypothese (Brosschot et al., 2006). Bovendien heeft onze longitudinale dagboekstudie de '*perseverative cognition*' hypothese uitgebreid naar het dagniveau. Ten slotte verschaffen de studies in dit proefschrift meer inzicht in het lange- en korte termijn beloop van stress en slaap.

Niettemin kennen de studies in dit proefschrift een aantal beperkingen die in toekomstig onderzoek aangepakt moet worden: We maakten voornamelijk gebruik van zelfrapportage om werkstress, piekeren en slaap te onderzoeken (met uitzondering van hoofdstuk 6 waarin slaap tevens op een objectieve manier werd gemeten). Ook werden sommige concepten met een enkel item gemeten. Een andere beperking betreft de beoordeling van piekeren in de longitudinale dagboekstudie. Hoewel het '*multiple-response*' item gedetailleerde en relevante informatie over de inhoud van het piekeren gaf, ontbrak een optimale beoordeling van de duur en intensiteit van de piekergedachtes. Een ander probleem betreft de conclusies die uit de mediatieanalyse in de longitudinale dagboekstudie getrokken kunnen worden. Aangezien deelnemers met behulp van het pieker-item piekeren tijdens bedtijd en/of 's nachts beoordeelden, kon niet ontrafeld worden of piekeren in de avond geleid heeft tot meer slaapverstoringen tijdens de nacht of dat slaapverstoringen piekeren faciliteerden.

PRAKTISCHE AANBEVELINGEN

Vanuit een valorisatie-perspectief moet, waar mogelijk, de eerste stap naar werkstress-preventie een werkgerichte aanpak betreffen. Goed ontworpen en gezond werk is van groot belang om werkstress te voorkomen. Dit zijn banen gekenmerkt door uitdagende (maar niet te hoge) taakeisen, voldoende autonomie, sociale steun, werkvariatie en een goed werk-rust schema. Daarnaast adviseren wij organisaties om werknemers praktische hulpmiddelen te bieden die werknemers kunnen helpen in tijden van stress en piekeren. Denk daarbij bijvoorbeeld aan werknemer-georiënteerde werk(tijd)flexibiliteit, het beperken van overwerk en/of het bevorderen van herstel na het werk en het psychologisch loskomen van het werk bijvoorbeeld door middel van fitnessclub lidmaatschappen, psychologische ondersteuning, en het aanbieden van cursussen om stressmanagement-technieken en/of slaaphygiëne te verbeteren. Als een laatste redmiddel kunnen werknemers met chronische stressklachten profiteren van interventies gericht op het verminderen van stress-gerelateerde gezondheidsproblemen (bijvoorbeeld door het aanbieden programma's omtrent lichamelijke beweging voor medewerkers die vroege tekenen van burn-out rapporteren).

De volgende, specifiekere praktische implicaties volgen uit de bevindingen omtrent de reciproke relaties tussen stress, piekeren en slaap en piekeren als onderliggend mechanisme in de stress-slaap relatie: Werknemers en werkgevers moeten zich ervan bewust zijn dat hoge stress niet alleen gerelateerd is aan een verminderde slaapkwaliteit, maar dat slechte slaapkwaliteit ook gerelateerd is aan een toename van stress. Deze wederzijdse beïnvloeding van stress en slaap maakt duidelijk dat slaapklachten een punt van aanpak kunnen zijn voor het omgaan met problematische stress (bijvoorbeeld door middel van verbetering van de slaaphygiëne). Bovendien doen werknemers er goed aan om te proberen om piekeren en de bijbehorende stress en slaapklachten te verminderen door afleiding te zoeken en door het verrichten van activiteiten die ontspanning na het werk stimuleren (bijvoorbeeld regelmatig bewegen en het ondernemen van (andere) vrijetijdsactiviteiten die positief affect bevorderen).

CONCLUSIE

De wetenschappelijke studies in dit proefschrift tonen aan dat er temporele en reciproke relaties bestaan tussen werkstress(oren), piekeren en slaap. Dit proefschrift heeft tevens aangetoond dat piekeren een belangrijk onderliggend mechanisme is in de reciproke relatie tussen stress en slaap.

Deutsche Zusammenfassung

EINLEITUNG

Forschung im Fachgebiet der Arbeits- und Gesundheitspsychologie hat gezeigt, dass fordernde Arbeit eine wichtige Ursache von Stress ist. Arbeiten unter stressigen Bedingungen erfordert kognitive, emotionale und/oder körperliche Anstrengung, die mit psycho-physiologischer Belastung verbunden ist. Nach der ‚*Effort-Recovery'* Theorie (Meijman & Mulder, 1998) ist eine ausreichende Erholung während oder nach der Arbeit entscheidend, um Effekte dieser Belastung zu reduzieren, und den psycho-physiologischen Systemen die Rückkehr zu ihrem Ausgangsniveau zu ermöglichen. Falls man aber bereits vor neuen Herausforderungen steht, wenn der Erholungsprozess noch nicht vollständig abgeschlossen ist, ist zusätzlicher Aufwand erforderlich, was die Anforderungen an den Erholungsprozess noch weiter erhöht und wodurch die negativen Effekte der psycho-physiologischen Belastung akkumulieren. Laut der ‚Allostatic Load' Theorie (McEwen, 1998) führt ein chronisches Ungleichgewicht zwischen Anstrengung und Erholung zu dem physischen Zustand ‚allostatic load', der mit negativen Gesundheitsauswirkungen verbunden ist. Obwohl der Zusammenhang zwischen fordernder Arbeit, Stress und Gesundheitsrisiken bereits erforscht worden ist, ist nur relativ wenig bekannt über den Zeitverlauf von und Zusammenhang zwischen Stress und Erholung (von Tag zu Tag oder Woche zu Woche) in Erwartung eines stressigen Ereignisses. Es ist wichtig diesen Zeitverlauf zu verstehen. Diese neuen Erkenntnisse können zum Verständnis der Wechselwirkung zwischen Stress, Erholung und Gesundheit beitragen.

Schlaf ist eine der bedeutungsvollsten Erholungsmöglichkeiten, fördert die psycho-physiologische Erholung von Stress, und ist somit essentiell für die Erhaltung der Gesundheit. Stress ist einer der wichtigsten Faktoren, die eine gute Nachtruhe beeinträchtigen. Es gibt Hinweise darauf, dass stressbedingte kognitive Prozesse eine wichtige Rolle bei stressbedingten Schlafstörungen spielen. In der wissenschaftlichen Literatur wird ein solcher negative Denkprozess ‚*perseverative cognition*' genannt, was in der deutschen Sprache dem Begriff ‚grübeln' am nächsten kommt. Grübeln wird als eine kognitive Beschäftigung mit vergangenen oder zukünftigen Stressoren definiert.

Bisher haben nur wenige Forscher die Zusammenhänge zwischen Stress, Grübeln und Schlaf untersucht. Diese bisherigen Studien deuten auf einen negativen Zusammenhang zwischen Arbeitsstress und Schlaf hin, aber Längsschnittstudie mit einem Schwerpunkt auf den zeitlichen Zusammenhang zwischen Arbeitsstress und Schlaf sind selten. Daher sind die empirischen Erkenntnisse zum zeitlichen Zusammenhang zwischen Stress, Grübeln und Schlaf begrenzt. In der Theorie ist der mögliche kausale Zusammenhang zwischen Stress(oren) und

Schlaf reziprok, auch wechselseitig genannt: Neben dem traditionellen Zusammenhang (z.B. Arbeitsstress beeinflusst darauffolgenden Schlaf), beschreibt die *‚stressor creation'* Hypothese (Bowling & Jex, 2013; Spector et al., 2000) einen umgekehrt-kausalen Zusammenhang, in dem schlechter Schlaf zu einem Anstieg der tatsächlichen oder wahrgenommenen Stressoren führt. Eine Schwäche der bisherigen empirischen Studien ist, dass Grübeln als erklärender Mechanismus im Arbeitsstress-Schlaf- Zusammenhang zumeist übersehen wurde, und daher die genaue Rolle von Grübeln in diesem Zusammenhang noch unklar ist.

Um diese Wissenslücken zu füllen, waren die wichtigsten Ziele dieser Dissertation (i) den zeitlichen Zusammenhang zwischen Arbeitsstress(oren), Grübeln und Schlaf zu untersuchen, (ii) die Rolle von Grübeln als potenzieller, erklärender Mechanismus im Stress-Schlaf Zusammenhang zu verstehen, und (iii) den Zeitverlauf von Stress und Schlaf zu erforschen.

ERGEBNISSE ALLER STUDIEN

In Kapitel 2 wird die Fachliteratur bezüglich des zeitlichen Zusammenhangs zwischen psychosozialen Arbeitseigenschaften (d.h., Arbeitsstressoren) und Schlafqualität auf systematische Weise dargestellt. Diese Studie zeigt, dass die meisten Studien empirische Beweise liefern für einen negativen Zusammenhang zwischen Arbeitsbelastung und Schlafqualität, und einen positiven Zusammenhang zwischen Autonomie und Schlafqualität. Jedoch zeigte eine Qualitätsprüfung der bisherigen Forschung auch, dass qualitativ hochwertige Studien über den zeitlichen Zusammenhang zwischen Arbeitsstressoren und Schlafqualität selten sind. Darüber hinaus wurde in den meisten Studien dem umgekehrt-kausalen Zusammenhang zwischen Stressoren und Schlaf keine Aufmerksamkeit geschenkt, und wurde Grübeln als potentieller, erklärender Mechanismus übersehen. Um die Mängel bisheriger Forschung zu beheben, wurden zwei Längsschnittstudien durchgeführt.

In Kapitel 3 und 4 werden diese beiden langfristigen full-panel Längsschnittstudien beschrieben. Diese bieten einen Einblick in den zeitlichen Zusammenhang zwischen Stress(oren), arbeitsbedingtem Grübeln und Schlafqualität. Die Längsschnittstudie in Kapitel 3 (zwei Messungen innerhalb einer großen, heterogenen Stichprobe der niederländischen Arbeitsbevölkerung) zeigt einen positiven und reziproken, zeitlichen Zusammenhang zwischen Arbeitsstress und arbeitsbedingtem Grübeln. Zwischen arbeitsbedingtem Grübeln und Schlafqualität wurde ein negativer und reziproker, zeitlicher Zusammenhang gefunden. Arbeitsbedingtes Grübeln konnte den negativen Zusammenhang zwischen Stress und darauf-

folgender Schlafqualität vollständig erklären, beziehungsweise fungierte als Mediator im Stress-Schlaf-Zusammenhang. In der full-panel Längsschnittstudie in Kapitel 4 (3 Messungen) wurden die gleichen reziproken, zeitlichen Zusammenhänge gefunden wie in Kapitel 3, und die Folgerungsschlüsse wurden erweitert, da Arbeitsstressoren, in diesem Falle Arbeitsbelastung, anstatt Arbeitsstress untersucht wurden. Arbeitsbedingtes Grübeln war ein erklärender Mechanismus (d.h., Mediator) im normalen und umgekehrt-kausalen Zusammenhang zwischen Arbeitsbelastung einerseits, und nächtlichen Schlafstörungen und Aufwachproblemen andererseits. Darüber hinaus klagten Arbeitnehmer mit einer chronisch hohen Arbeitsbelastung über mehr Schlafstörungen, Probleme mit dem Aufwachen und arbeitsbedingtes Grübeln über längere Zeit, im Vergleich zu Arbeitnehmern mit einer stabil-mäßigen oder stabil-niedrigen Arbeitsbelastung.

Die ersten drei Studien konzentrierten sich auf Langzeitprozesse. In Kapitel 5 und 6 wurden Kurzzeitprozesse (d.h. auf Tagesebene, von Tag zu Tag) hervorgehoben. Diese Kapitel basieren jeweils auf einer Tagebuchstudie, in der Doktoranden begleitetet wurden die auf ein stressiges Lebensereignis (in diesem Falle ihre öffentliche Dissertationsverteidigung) warteten und sich davon im Anschluss erholten. In Kapitel 5 lag der Schwerpunkt auf dem Zeitverlauf von Stress, Müdigkeit und Schlafqualität vor und nach diesem stressigen Ereignis. Das Stressniveau der Doktoranden stieg in Erwartung der Verteidigung und nahm unmittelbar nach der Verteidigung wieder ab. Müdigkeit blieb unverändert vor der Verteidigung, stieg aber unmittelbar nach der Verteidigung, bevor sich Müdigkeit dann wieder langsam verringerte. Schlafqualität verschlechterte sich vor der Verteidigung nicht, aber verbesserte sich unmittelbar nach der Verteidigung. Einen Monat vor der Verteidigung war das Stressniveau der Doktoranden im Vergleich zu einem Monat nach der Verteidigung schon erhöht. Außerdem nahm Stress durch negative Erwartungen zu, und durch Erwartungen eines guten Ausgangs der Verteidigung ab (alles auf Tagesebene, also von Tag zu Tag). Erwartung eines guten Ausgangs der Verteidigung war ein positiver Prädiktor für Schlafqualität auf Tagesebene.

In Kapitel 6 wurden natürliche, tägliche Veränderungen in Stress, Grübeln in Erwartung des stressigen Lebensereignisses, und sowohl objektive als auch subjektive Schlafparameter gemessen. Die statistischen Analysen zeigten, dass Stress und Grübeln auf Tagesebene (von Tag zu Tag) zusammenhingen. Grübeln ging wiederum einher mit verschiedenen objektiven und subjektiven Schlafparametern (d.h. objektive Schlafeffizienz, subjektive Schlafqualität, subjektive und objektive Anzahl und Dauer des nächtlichen Erwachens). Tägliches Grübeln schien ein erklärender Mechanismus im Zusammenhang zwischen Stress und Schlafqualität zu sein. Dabei muss beachtet werden, dass in der Tagebuchstudie nur der traditionelle kausale Zusammenhang untersucht wurde, d.h. dass viel

Stress für vermehrtes Grübeln sorgte, und dieses wiederum einen negativen Einfluss auf Schlaf hatte. Dieser Zusammenhang wurde für subjektive Schlafqualität, objektive Schlafeffizienz und subjektive Erfahrungen zur Dauer des nächtlichen Erwachens gefunden.

DISKUSSION

Zeitlicher Zusammenhang zwischen Arbeitsstress(oren), Grübeln und Schlaf

Die systematische Zusammenfassung der Fachliteratur (Kapitel 2) fand Beweise für einen zeitlichen Zusammenhang zwischen Arbeitsbelastung und Autonomie einerseits, und Schlafqualität andererseits. Unsere Zusammenfassung der Fachliteratur ergab auch, dass in bisherigen Studien umgekehrt-kausale und reziproke zeitliche Zusammenhänge zwischen Schlaf und Stress(oren) weitgehend vernachlässigt wurden. Darüber hinaus wurde kaum untersucht, welche Rolle Grübeln im Zusammenhang zwischen Stress und Schlaf spielt. In beiden Längsschnittstudien (Kapitel 3 und 4) wurden reziproke, negative Zusammenhänge zwischen Arbeitsstress(oren) und Grübeln und zwischen Grübeln und Schlafqualität gefunden. Darüber hinaus wurden in Kapitel 6 die zeitlichen Zusammenhänge zwischen Stress, Grübeln und Schlaf auf der Tagesebene (von Tag zu Tag) gefunden. Aber in dieser Studie wurden nur der traditionelle, zeitliche Zusammenhang von Stress, über Grübeln zu Schlaf untersucht. In allen Studien dieser Dissertation war der direkte Zusammenhang zwischen Arbeitsstress(oren) und Schlaf nicht eindeutig oder nicht existent, sobald arbeitsbedingtes Grübeln in das Modell aufgenommen wurde. Diese Ergebnisse unterstützen die Vermutung, dass Grübeln eine wichtige vermittelnde Rolle im Stress-Schlaf-Zusammenhang spielt.

Grübeln als erklärender Mechanismus des Stress-Schlaf-Zusammenhangs

Die beiden großen Längsschnittstudien (Kapitel 3 und 4) und die Tagebuchstudie (Kapitel 6), die in dieser Dissertation präsentiert wurden, zeigen, dass Grübeln ein erklärender Mechanismus im zeitlichen Zusammenhang zwischen Stress(oren) und darauffolgende Schlafqualität war. Unsere Ergebnisse unterstützen die *‚perseverative cognition'* Hypothese (Brosschot et al., 2006), die davon ausgeht, dass eine kontinuierliche mentale Repräsentation von Stressoren, anstatt oder zusätzlich zu den Stressoren selbst, ausreicht, um eine langfristige physiologische Aktivierung zu verursachen und dadurch Schlafqualität zu verstören. Die Ergebnisse der Tagebuchstudie erweitern die *‚perseverative cognition'* Hypothese, und zeigen,

dass diese Hypothese auch auf Tagesebene zutrifft. Außerdem zeigt Kapitel 4, dass Grübeln sowohl ein erklärender Mechanismus im zeitlichen Zusammenhang zwischen Arbeitsbelastung und nächtlichen Schlafstörungen ist (d.h. vor allem Probleme mit Schlafkontinuität), als auch im Zusammenhang zwischen Arbeitsbelastung und Aufwachproblemen (d.h. sich nicht ausgeruht fühlen am nächsten Morgen). Des Weiteren stellte sich in Kapitel 6 heraus, dass die vermittelnde Rolle von Grübeln nicht nur auf die subjektive Erfahrung von Schlafstörungen zutrifft, sondern auch auf objektive Schlafqualität (z.B. objektive Schlafeffizienz). Neben dem traditionellen kausalen Zusammenhang zwischen Stress(oren) und Schlaf, wurde in Kapitel 4 gefunden, dass Grübeln auch den umgekehrt-kausalen Zusammenhang zwischen Schlafqualität und Stressoren vermittelt. Dieser Befund steht im Einklang mit der *‚stressor creation'* Hypothese (Bowling & Jex, 2013; Spector et al, 2000), was darauf schließen lässt, dass schlechter Schlaf zu negativen (wahrgenommenen) Veränderungen in der Arbeitsumgebung führen kann. Es kann geschlussfolgert werden, dass Grübeln in der Tat ein wichtiger, erklärender Mechanismus sein kann in sowohl dem kurzfristigen, als auch langfristigen, reziproken und negativen Zusammenhang zwischen Stress(oren) und Schlaf.

Zeitverlauf von Stress und Schlaf

In Kapitel 4 und 5 wurden der lang- und kurzfristige Zeitverlauf von Stress und Schlaf untersucht. Arbeitnehmer, die über einen Zeitraum von vier Jahren einer chronisch hohen Arbeitsbelastung ausgesetzt waren, klagten über eine geringere Schlafqualität (d.h. mehr Schlafstörungen und mehr Probleme mit dem Aufwachen) und häufigeres arbeitsbedingtes Grübeln als Arbeitnehmer mit einer mäßigen oder niedrigen Arbeitsbelastung. Unsere Tagebuchstudie verschaffte Einblicke in die Kurzeitprozesse, und zeigte, dass Doktoranden in Erwartung des stressigen Lebensereignisses (ihre öffentliche Dissertationsverteidigung) bereits vier Wochen vor dem stressigen Ereignis erhöhten Stress erfuhren. In den Wochen vor dem stressigen Ereignis nahm Stress noch mehr zu, verringerte sich aber sofort nach dem Ereignis wieder. Schlafqualität war relativ hoch und blieb stabil in Erwartung des stressigen Ereignisses, und in den vier Wochen danach, und stieg nur leicht unmittelbar nach dem stressigen Ereignis an. Dieser Befund legt nahe, dass Teilnehmer während des gesamten Zeitraums trotz Stress relativ gut geschlafen haben und sich im Schlaf erholt haben. Die Ergebnisse in Bezug auf die Lang- und Kurzeitprozesse des Zeitverlaufs von Stress, Grübeln und Schlaf sind weitgehend im Einklang mit der *‚Effort-Recovery'* Theorie (Meijman & Mulder, 1998) und der *‚Allostatic Load'* Theorie (McEwen, 1998), die eine theoretische Grundlage für den Zeitverlauf von Stress und Schlafstörungen bieten. Die empirischen Studien dieser Dissertation geben eine Teilantwort auf die Frage, wie

Stress und Schlaf sich im Laufe der Zeit entwickeln. Wenn man für eine lange Zeit (von Monaten bis Jahren) durch Arbeit oder andere bedeutende, stressige Ereignisse angespannt ist, wird sich der erfahrene Stress zunächst erhöhen, so suggerieren unsere Studien. Nach diesem anfänglichen Anstieg wird sich Stress aber vermutlich irgendwann stabilisieren und nicht weiter ansteigen. Gleichzeitig bleiben Grübeln und erfahrene Schlafprobleme auch beständig. Erst nachdem sich der Stressor vermindert oder ganz verschwunden ist, werden sich das Stressniveau verringern und Schlafqualität wieder verbessern.

STÄRKEN UND SCHWÄCHEN

Die Studien, die in dieser Dissertation präsentiert wurden, haben einige wichtige Stärken, wie zum Beispiel die qualitativ hochwertigen Forschungsdesigns und die langfristigen full-panel Längsschnittstudien und Tagebuchstudien. Außerdem wurden sowohl subjektive als auch objektive Methoden genutzt, um Schlaf zu messen und wurden Längsschnittstudien mit verschiedenen Zeitintervallen verwendet. Zum Beispiel wurden sowohl Längsschnittstudien mit Zeitintervallen von einem bis zu mehreren Jahren durchgeführt als auch kurzfristige Tagebuchstudien mit Tages- oder Wochenzeitintervallen. Durch den Gebrauch dieser qualitativ hochwertigen Forschungsdesigns konnten die reziproken zeitlichen (sowohl langfristigen und kurzfristigen) Zusammenhänge zwischen Stress(oren), Grübeln und Schlafqualität untersucht werden, was vorsichtige Schlussfolgerungen über Kausalität ermöglichte.

Eine weitere wichtige Stärke ist der Beitrag und die Erweiterung wichtiger Theorien in der Stress- und Erholungsliteratur. In dieser Arbeit wurden nicht nur Beweise für ‚normalen', sondern auch für ‚umgekehrt-kausalen' zeitlichen Zusammenhang gefunden zwischen Stress, Grübeln und Schlaf, und somit Beweise geliefert für die ‚*stressor creation*' Hypothese (Bowling & Jex 2013 Spector et al, 2000). Des Weiteren ist eine der wichtigsten Erkenntnisse, dass gezeigt wurde, dass Grübeln ein erklärender Mechanismus im reziproken Zusammenhang zwischen Arbeitsstress und Schlaf ist, was die ‚*perseverative cognition'* Hypothese (Brosschot et al., 2006) bestätigt. Darüber hinaus hat die Tagebuchstudie die ‚*perseverative cognition'* Hypothese erweitert und gezeigt, dass diese Hypothese auch auf Tagesebene zutrifft. Zu guter Letzt bieten die Studien in dieser Dissertation mehr Einblicke in den lang- und kurzfristigen Zeitverlauf von Stress und Schlaf.

Dennoch haben die Studien in dieser Dissertation einige Schwächen, die in zukünftigen Studien aufgegriffen werden sollten. Bei der Erforschung von arbeitsbedingtem Stress, Grübeln und Schlaf (mit Ausnahme von Kapitel 6, in dem

Schlafparameter auch objektiv erfasst wurden) wurden lediglich einige Einzelfragen verwendetet um die Konzepte zu erfassen anstatt validierter, längerer Fragebögen. Eine weitere Einschränkung betrifft die Bewertung von Grübeln in der Tagebuchstudie. Obwohl die ‚*multiple response*' Frage detaillierte und relevante Informationen über den Inhalt der Grübel-Gedanken lieferte, fehlte der Frage eine optimale Bewertung der Dauer oder Intensität der Grübel-Gedanken. Eine weitere, verwandte, Schwäche betrifft die Schlussfolgerung, die aus der Mediationsanalyse in der Tagebuchstudie gezogen werden kann. Da die Grübel-Frage das Grübeln der Teilnehmer während der Schlafenszeit und/oder der Nacht erfragte, konnte nicht eindeutig bestimmt werden ob Grübeln am Abend zu mehr Schlafstörungen in der Nacht führte, oder ob Schlafstörungen das Grübeln während des nächtlichen Erwachens verursachten.

PRAKTISCHE IMPLIKATIONEN

Aus Sicht der Valorisierung sollte, soweit möglich, der erste Schritt arbeitsorientierte Prävention von Stress sein. Hochwertige, wohldurchdachte Arbeitsstellen mit Augenmerk für betriebliche Gesundheitsfürsorge und Wohlbefinden sind sehr wichtig, um Arbeitsstress zu vermeiden. Diese Arbeitsplätze werden gekennzeichnet durch eine herausfordernde (aber nicht zu hohe) Arbeitsbelastung, ausreichende Autonomie, soziale Unterstützung, Jobvielfalt und einen ausgeglichenen, gut geplanten Arbeit-Ruhezeitplan. Darüber hinaus wird es Organisationen empfohlen, ihren Arbeitnehmern Möglichkeiten aufzuzeigen, mit Stress und Grübeln umzugehen. Dies kann zum Beispiel geschehen durch mitarbeiterorientierte Arbeitszeitflexibilität, Reduktion von Überstunden und/oder durch Förderung der Erholung nach der Arbeit und psychologische Ablösung von der Arbeit durch Fitnesscenter-Mitgliedschaften, psychologische Unterstützung und Kurse, die helfen Stress-Management-Techniken und/oder Schlafhygiene zu verbessern. Als letzten Ausweg könnten Arbeitnehmer, die unter (chronischem) Stress leiden, von mitarbeiterorientierten Interventionen profitieren, die zum Ziel haben, stressbedingte Gesundheitsprobleme zu reduzieren (z.B. Lauftraining für Arbeitnehmer mit frühen Anzeichen von Burnout).

Die folgenden praktischen Implikationen sind zurückzuführen auf unsere Erkenntnisse hinsichtlich der Reziprozität des Stress-Grübeln-Schlaf- Zusammenhangs und der Rolle von Grübeln als erklärender Mechanismus im Stress-Schlaf-Zusammenhang. Arbeitnehmer und Arbeitgeber sollten darüber informiert werden, dass hoher Stress nicht nur mit einer verminderten Schlafqualität einhergeht, sondern dass schlechte Schlafqualität auch mit einem Anstieg von

tatsächlichem oder wahrgenommenem Stress zusammenhängt. Die Erkenntnis, dass der Stress-Schlaf-Zusammenhang bidirektional ist, sollte das Bewusstsein für die Möglichkeit erhöhen, dass Schlafbeschwerden auch ein Angriffspunkt für den Umgang mit problematischem Stress sein können (z.B. durch Verbesserung der Schlafhygiene). Darüber hinaus sollten Mitarbeiter versuchen, Grübeln und damit verbundenen Stress und Schlafbeschwerden zu vermindern durch Ablenkung und Aktivitäten nach der Arbeit, die Loslösung von der Arbeit stimulieren, wie zum Beispiel regelmäßige Bewegung und andere Aktivitäten, die positiven Affekt fördern.

SCHLUSSFOLGERUNG

Die in dieser Dissertation präsentierten empirischen Studien ergaben Einblicke in die zeitlichen Zusammenhänge zwischen arbeitsbedingtem Stress(oren), Grübeln und Schlaf, und lieferten Beweis für negative, reziproke Zusammenhänge zwischen diesen Konzepten. Außerdem hat diese Dissertation gezeigt, dass Grübeln ein wichtiger erklärender Mechanismus des reziproken Stress-Schlaf-Zusammenhangs ist.

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- Van Laethem, M., Beckers, D.G.J., Geurts, S.A.E., Magnusson Hanson, L.L., Kecklund, G., & Leineweber, C. (submitted). Perseverative cognition as an explanatory mechanism in the relation between job demands and sleep quality.

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Curriculum Vitae

Michèlle Van Laethem was born on June 28th 1987 in Warstein, Germany. After growing up bilingually (German/Dutch) and completing the *Abitur,* Michèlle spent a year in the United States as an Au Pair. Afterwards, Michèlle decided to study Psychology at Maastricht University in the Netherlands. There she completed her Bachelor's degree in Psychology, part of which at the University of Victoria in Canada. After successfully completing her Bachelor's degree in 2010, Michèlle enrolled in the Master track 'Work and Organizational Psychology' at Maastricht University. During her studies she developed a passionate interest in interdisciplinary research. After finishing her Master's degree (cum laude), Michèlle accepted a PhD position at the Behavioural Science Institute (BSI) of the Radboud University in Nijmegen, the Netherlands. At the BSI she worked in the Work, Health and Performance group and performed research on the relationship between stress and sleep. During her PhD Michèlle spent time abroad in Sweden, Finland, and the Unites States to perform research, teach, as well as present her work at several conferences. This resulted in various successful collaborations and partnerships with researchers abroad. In June 2016, Michèlle finished her dissertation and started a new job as Assistant Professor at the Department of Work and Organizational Psychology at the University of Amsterdam in the Netherlands. In Amsterdam she will continue her work on stress and sleep.

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